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NUMBER 2 · JULY 1958

Plant Nutrients—Foliar or Soil Application? **2**
by P. Allan

Red Ring of Coconuts—A Problem for the Nematologist **5**
by D. W. Fenwick

Insecticide Resistance in Disease-carrying Insects, Part 2 **8**
by J. R. Busvine

Killing Broomrape in Tobacco **14**

Britain's First National Silage Demonstration. (Sponsored by Shell) **16**

International Co-operation in Crop Protection **20**
by V. E. Wilkins

British Developments in Aerial Spraying **24**
by W. R. Caseby

Phosdrin—A New Insecticide **28**
by A. G. Richardson

Books **31**

Reducing the Cost of Blister Blight Control **34**
by B. N. Webster

Mediterranean Fruit-Fly Eradicated in Florida **36**

ERRATUM. Page 7
The fourth figure in the photograph is Dr. G. Steiner—not Dr. Skinner

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Our cover picture is of rice being winnowed near Manila, in the Philippines. Rice is the biggest crop in the Philippines and is the country's staple food cereal.

SHELL PUBLIC HEALTH AND AGRICULTURAL NEWS, ST. HELEN'S COURT, GREAT ST. HELEN'S, LONDON, E.C.3

Plant Nutrients

FOLIAR OR SOIL APPLICATION?

by **P. Allan,** *The Shell Petroleum Company Ltd.*

The capacity of many plants to absorb either macro or micro plant nutrients through their leaves is well-known. Current modern belief is that entry is through certain parts of the cuticle and not through the stomata as earlier imagined. Nor does the latest work indicate that there is any different rate of absorption between the upper and lower surfaces. Leaf absorption is much more rapid than uptake through the roots and for this and other reasons, spraying of the above-ground parts of plants has for long been an approved technique for correcting deficiencies in minor elements such as iron, manganese, copper and molybdenum.

The possibilities of foliar applications of the major plant nutrients, nitrogen, phosphorus and potassium, have received more recent examination, work on the problems involved having been stimulated by the great post-war expansion in the use of spraying equipment on both farms and market garden and fruit crops. Sufficient experimental and other evidence is now available for an assessment to be made of the merits of the foliar application technique compared with the conventional method of soil application.

Of the three major nutrients, foliar application of phosphorus offers fewer possibilities than that of nitrogen or potash. Phosphorus is easily fixed in the soil and made unavailable to plants, so that spray application theoretically should provide an economical method of using this element. But most agricultural crops need their phosphorus early in the growing season when there is only a small leaf area to retain the spray. In practice, soil application is therefore preferable.

Spray application of potash should be more promising, but surprisingly little work has been reported with this element. There is some evidence that sprayed potash can give better results than soil dressings on some tropical crops, while supplemental spray additions to basic soil applications have been found valuable on lucerne grown on very light sandy soils.

Most nitrogenous fertilisers are readily soluble in water but only the two most concentrated forms—ammonium nitrate and urea—have been extensively worked with. Both of them have upper limits beyond which they must not be used if scorching of foliage is to be avoided, and urea, in addition, must be very low in its content of biuret, a toxic product formed during crystallisation or granulation ('prilling'). The tolerance of plants to urea or ammonium nitrate sprays varies considerably, from cereals at one end of the scale to the very sensitive cucurbits at the other.

Cereals

A number of investigations into the use of these nitrogenous fertilisers has been carried out on cereals,

in which two theoretically attractive ideas have been tested—namely, combination of application of nitrogen and selective weedkillers, and late-season application of nitrogen to increase the grain protein content. The combination of nitrogen (as either urea or ammonium nitrate) and weedkiller was, however, shown at Rothamsted Experimental Station to be of no advantage because of low uptake of nitrogen by the plants. Only about half as much nitrogen was recovered in the crop from spray applications as from equivalent soil applications. The reason was to be found in the fact that, at the spray timing best for weed control, the crop's leaf system is too small in area to give good retention of the spray.

Such lower uptake from a liquid spray has been confirmed by work elsewhere. This work also included late-season spraying tests, which were found not to increase protein content as much as do solid applications. It seems unlikely that foliar application of nutrients to cereals will ever replace the conventional solid distribution method.

On grassland, similarly, spray applications have not been shown to increase either total yield or protein content over those given by solid applications. It may, nevertheless, be attractive to combine the application of nutrients with that of a herbicidal spray under some circumstances, though so far the practice has not become general.

Fruit Crops

Much work has been done on apples and other fruit crops for, where several cover sprays may have to be given for pest or disease control during the course of a season, the nutrient can take a "free ride" with a resulting saving in application costs. In order to avoid leaf damage, however, neither urea nor ammonium nitrate must be used at concentrations greater than 1.0 per cent., nor exceeding in total quantity the equivalent of 15 lb. nitrogen per acre at any one time.

It is possible under some circumstances to increase the concentration slightly if safeners such as molasses, sugar or starch are added. On the other hand, injury may range from serious to severe if the nutrient is used in combination with certain fungicides or insecticides such as lime-sulphur, dinitro compounds, arsenicals or organic mercury materials. Urea is compatible, and has been employed commercially, with zineb, ferbam, Dithane, wettable sulphur and Bordeaux mixture. Ammonium nitrate is less compatible and is preferably used alone.

In general, unless the nitrogen status of the soil and trees is very low, or the season unfavourable, it has not been found that addition of nitrogen through the leaves has any advantage over soil applications. But the technique can be valuable to stimulate growth in very dry seasons or to control nitrogen deficiencies which may show up in very wet seasons on light soils deficient in organic matter.

Vegetables

The use of foliar nutrition sprays on vegetables has been much investigated in the U.S. Tomatoes have been shown to tolerate no more than 4-5 lb. urea per 100 gal. of water, and no more than 150 gal. per acre of such a solution per application. Since a normal pest control programme could involve five to seven sprayings per crop a significant part of the nitrogen required could be applied in a combination spray. However, the general recommendation still is to apply the major part of the nitrogen as a basal dressing, to be supplemented by additional sprayed nitrogen as required.

Beans, cabbages, cauliflowers, celery and sweet corn are similar to tomatoes in having low tolerances, while cucumbers and other cucurbits are very susceptible to injury from foliar sprays. On the other hand, carrots, parsley and asparagus can stand up to 20 lb. urea per 100 gal. of water without injury—thus most of the nitrogen required by these crops can, if desired, be applied as a combination spray with insecticides or fungicides. Potatoes have a similar tolerance to these last-named vegetables but, since their overall needs of nitrogen are considerably greater, it is sounder commercial practice to apply fertilisers in solid form.

Of the temperate climate crops to which foliar sprays have been applied, mention must also be made of sugar-beet. Spraying six times in autumn with 100 gal. per acre of a 3 per cent. solution of ammonium nitrate, or equivalent urea, to test whether the protein content of the tops could be increased, did in fact have this effect, and to a greater extent than application of equivalent amounts of solid fertilisers at the same time. However, spraying reduced the sugar content of the roots, in some cases to a significant extent, and since most farmers would place a higher value on the sugar content of the roots than on the feeding-value of the tops, spraying would not appear to offer any overall advantage, at least when carried out at this late stage of growth.

Tropical Crops

Foliar application has proved much more successful and of greater commercial importance in the case of certain tropical crops—notably sugar cane, bananas, coffee and pineapples.

Spraying of cane with urea from the air has been practised in Hawaii, for example, since 1950. In these islands the crop has a somewhat longer growing period

than elsewhere and it is usual to make a number of applications of both nitrogen and potash fertilisers. When the cane has closed in, aerial application has considerable advantages and appears to be employed as routine practice on a considerable number of estates. A 50 per cent. solution of urea provides the nitrogen, and it has been found that up to 88 lb. nitrogen per acre in this form can be applied with a minimum of leaf scorch so long as there is 80 per cent. moisture in the cane sheaths at the time of application. Potash also has here been used in liquid form with particular success in that, because of the high fixation capacity of the Hawaiian soils, it is more efficiently utilised than is the case with soil applications.

Banana, like sugar cane, is a crop with large leaves and with a long period of growth. Moreover, because of the vital necessity of controlling Sigatoka disease, it is essential to spray many times during the course of a season with Bordeaux mixture or other fungicides. Apart from this fungicidal spraying, many of the big fruit companies irrigate with overhead sprinklers rather than by water flow over the soil surface. Conditions for applying plant nutrients by the foliar method are therefore virtually ideal, and the practice has been adopted on most of the large plantations in Central America. Urea is the selected form of nitrogen in this case.

Pineapples are epiphytic plants with a very poor root system and are consequently much better suited than most plants to receive their necessary supply of nutrients through their leaves. In both Hawaii and Puerto Rico it has been shown that up to 200 lb. urea per acre can be applied, in two early applications of 50 lb. and a last one of 100 lb., in all cases in 150 gal. of water per acre. With these relatively heavy foliage dosage rates it is especially important that the biuret content of the urea should be low. It should preferably be under 1 per cent., and crystalline urea is therefore more suitable than the prilled form.

Urea is sometimes employed on coffee as a foliar spray to provide supplemental nitrogen to that given in the basal dressing. The crop is treated in the post-blossom stage with a high-volume spray of sufficient concentration to provide 25 lb. nitrogen per acre. This practice has developed commercially in southern India, though so far has been little used elsewhere.

To summarise, therefore, it can be said that so far as annual and temperate-climate crops are concerned, foliar application is never likely to replace the conventional method of soil application. It may, however, have some value as a first aid measure under certain circumstances, on tree-fruits more so than on annual crops. On several common and important large-leaved and/or perennial tropical crops foliar spraying can, however, show substantial advantages, and its practice should increase considerably where such crops are grown under an 'estate' system of management. Of the major plant nutrients, nitrogen is the one best suited to this mode of application and, of the different forms of nitrogen, urea is the one of choice. For the correction of deficiences of minor elements foliar application is, in general, much preferable to soil application, especially in the case of manganese, copper, iron, zinc and molybdenum.

WHO Complete Malaria Survey

A survey of 99 countries and territories has recently been completed by the World Health Organization as a first step in its campaign to eradicate the world's most expensive disease—malaria.

Already, WHO state, malaria eradication has nearly been achieved in nine countries with a population of 231 million, and is well advanced in large areas of seven others (population 43 million). In another 44 countries (population 302 million) a beginning has been made, and in 16 countries, with a population of 580 million, eradication is now being planned.

Ten years ago, malaria struck 300 million people and caused 3 million deaths a year. Now, these figures have been halved, WHO declare.

Malaria is the world's greatest single cause of human debility, and it retards the development of many potentially fertile areas of the world. As examples of the need to eradicate the disease, WHO cite Mexico and India.

In Mexico, the loss of working time due to malaria is estimated at $18 million a year; the total cost of malaria eradication in this country within the next five years will be $21 million.

In India, loss of wage earning capacity due to customary six-day attacks of malaria is estimated at $30 million: since malaria decreases efficiency by about 25 per cent. during the whole year, loss on this account increases the total loss to $500 million a year. The total cost of malaria eradication in India by 1965 has been estimated at $114 million.

RED RING OF COCONUTS

A problem for the Nematologist

by **D. W. Fenwick,** D.Sc.

Director of the Red Ring Research Unit, Trinidad

Until recently a member of the nematology department at Rothamsted Experimental Station, Dr. Fenwick spent three months in Trinidad in 1956 investigating red ring disease of coconuts. This disease, which is associated with infestation by the nematode Aphelenchoides cocophilus, *is becoming an increasingly serious menace to copra production, and on some estates it is estimated that it is today reducing yields by 20-30 per cent. Dr. Fenwick has now returned to Trinidad to continue his studies on the biology and control of the disease.*

Red ring disease of coconuts has been shown to be due to the colonisation of the stem tissues of young palms by the nematode worm *Aphelenchoides cocophilus* (Cobb). It is an endemic disease of South and Central America and has been recorded in Venezuela, Columbia, Panama and British Honduras. Over the years it has spread to the Lesser Antilles, including Trinidad, Tobago, Grenada and St. Vincent.

The history of the disease in Trinidad is interesting in that up to about 1925 it does not appear to have caused excessive damage, probably because the worm was absent in most newly-planted areas, and the plants passed the susceptible age before the parasite had time to build up to a dangerous level. These older plantations were usually maintained by casual planting to fill gaps, so that the density of young trees of susceptible age was never very high; losses from the disease might have been very extensive but the immediate effect on output was not great and the danger due to the disease tended to be overlooked. Recently, however, there has been a tendency to fell old palms and replant whole fields. Under these conditions all the palms reach the age of maximum susceptibility at the same time and the losses due to red ring become more apparent. It is also possible that the higher density of young trees results in a more rapid build up of the parasite, thus aggravating the losses—so that the establishment of new plantations becomes difficult, if not impossible.

The disease was originally termed 'root disease' by Nowell (1918) who considered that it resulted from the infestation of roots; he realised the importance of the nematodes as causal agents: later he retracted his early view that the disease was primarily one of the roots and suggested that the red zone in the stem was the original site of infestation, and that root infestations were secondary to it.

Later work by Ashby (1921, 1921a), Bain and Fédon (1951), Tidman (1951) and Martyn (1953) confirmed the findings of Nowell that red ring disease was associated with the nematode *Aphelenchoides cocophilus*. There is no evidence that the worm can be present without the typical symptoms of disease appearing and, conversely, there is no recorded case of red ring without the worms; the conclusion must therefore be drawn that the nematode is the causal influence. Infestation can result from direct penetration of the aerial or underground parts of a tree: some evidence has been presented by Martyn and Bain and Fédon suggesting that the palm weevil, *Rhyncophora palmarum*, and ants can act as vectors. Neither of these authors, however, progressed far enough to assess the true importance of the palm weevil as a vector, nor to investigate the factors responsible for the spread of the disease in the field.

The writer visited Trinidad in 1956 and made further investigations into the disease, and reported on his findings (Fenwick, 1957).

Red ring was first described by Nowell. The most obvious symptom is a progressive yellowing and

browning of the leaves, starting with the lowest or oldest leaf and moving upwards till all the expanded leaves fail. The changes in any leaf usually start at the top and spread down to the base. These symptoms, whilst undoubtedly correct, need to be interpreted with care since yellowing and browning of leaves can result from a variety of causes, the most important of which is probably bad drainage. In such cases, however, the symptoms are more generalised throughout the tree than in the case of red ring, where yellowing and browning follow a definite sequence; thus in a moderately advanced state of the disease it is usual to find one or more of the lower leaves brown and nearly dead, the next two or three leaves a light yellow colour, and the youngest leaves normal.

This progressive change extending upwards occurs invariably in a tree suffering from red ring but can and sometimes does occur when no red ring is present. Some authors claim that red ring can bring about the collapse of a tree. The writer has never encountered such a case. Collapse is almost invariably associated with a generalised internal decay, due usually to weevil damage and sometimes to other causes.

Diagnosis

Diagnosis, to be definite, must be confirmed by the presence of reddened tissue; this is not always easy to find in the early stages of the disease and is not in itself specific, since any injury or damage to coconut tissues results in red coloration: it is necessary to find the characteristic ring of reddened tissue (usually about 1-2 in. below the surface) or, in very early infestations, a central mass in the base of the tree. Even then it is desirable that this be confirmed by the recovery of recognisable *Aphelenchoides cocophilus*.

During his stay in Trinidad in 1956, the writer examined a number of infected trees in order to gain information on the development of the disease. It appears reasonably certain that in nearly every case there is a central mass of reddened tissue in the base of the tree and there is good reason for believing this to be a very early stage in the colonisation of the stem by nematodes. Very frequently this reddened mass of tissue extends radially outwards, then upwards, to form a basin-shaped mass within the base of the stem. Later, the sides of the basin may extend upwards for a variable distance to form a cylinder of reddened tissue about 1-2 in. below the trunk surface.

The distribution of worms within the reddened area is interesting. When discoloured tissues is confined to a small area in the base of the bole, males, females and larvae are to be found all together in variable proportions; when the red tissue has extended outwards to form a basin the adults appear to be confined to the upper edges; when the disease is well advanced and the characteristic cylinder has been formed, it is difficult to find any adults except at the tip of the cylinder.

It is therefore very probable that infestation starts in the base of the tree. The method of entry of the worms into this area is uncertain but there are indications that it occurs via the roots. The writer has demonstrated the presence of worms in the roots on several occasions and in a few cases has succeeded in tracing a continuous trail of worms extending from individual roots up into the reddened area in the bole. The presence of red ring worms in soil around infested roots has also been established; also in a few cases red ring worms have been recovered from soil in coconut plantations.

The question of transmission of worms by coconut weevils is one which requires further study. The writer's own view is that the subject is largely of academic interest. Weevil attack is in itself serious and can result in the death of a young tree without any help from red ring. Where both weevil and red ring are present, the tree usually dies from weevil attack. Only rarely in the case of light weevil attacks do the weevil tracks in the tissue coincide with the reddened area. Laboratory tests indicate that weevils can carry red ring worms but prolonged soaking is necessary to dislodge them from the beetle, so that the chances of worms falling off a weevil when it visits a tree seem rather slender. Even if weevils are of no importance whatever, their control is still of the greatest importance since they constitute a most serious pest in their own right. In some estates in Trinidad and Tobago they are at least as important as red ring in causing the death of young trees.

A rather disquieting feature came to light during the writer's previous visit to Trinidad. In some areas old trees were found to be dying from red ring. These trees exhibited a variety of symptoms which were not at all typical of red ring as seen in young trees—diagnosis was in all such cases based on the recovery of living red ring worms. It is impossible as yet to assess the importance of the disease as a factor affecting older trees, but should the incidence of the disease in older trees increase, the position of the coconut industry would be even more seriously menaced than at present.

Many workers have suggested that the disease can be spread by using infected seed nuts. The writer has not been able to find any evidence that the infection can penetrate to the nut on the tree. Dropped nuts, however, frequently contain soil nematodes in the husk; it is probable that these penetrate through bruised areas resulting from impact with the soil when the nuts fall. If, therefore, red ring worms are present

in the soil it is possible that they could gain entry into the husk and start new infestations if these nuts were planted.

Control Measures

At the present stage of knowledge it is impossible to discuss control measures except in a speculative sense. The old policy of 'cut and burn' is still important, although it is probable that burning must be more thoroughly carried out than is customary. Further research using various plant poisons may result in a cheaper and more convenient alternative.

Until more is known about the habits and biology of the worm in soil, the value of soil fumigation is questionable. If, as appears probable, entry is from the soil then fumigation might be a practical method of control. It must be realised, however, that efficient control by this method would be more difficult for coconuts than for an annual crop such as tomatoes, since it would be necessary to keep the worm population down to a low level for several years until the plant had survived the susceptible age. In this connection the use of the relatively non phytotoxic nematocide Nemagon might yield valuable results.

If the transmission of the disease by seed nuts were confirmed, then its spread to new areas might be considerably retarded by the use of clean seed. This might be accomplished by the use of hand-picked nuts from healthy trees, or alternatively by treatment of seed nuts to eradicate any contained worms. This might be accomplished by hot water treatment or alternatively by fumigation. It is doubtful, if such treatment became desirable, whether it could be carried out by the planter since in most cases where other seeds have been so treated the conditions for successful treatment have had to be very rigidly controlled.

It appears, therefore, that although research has been carried out in red ring disease of coconuts it is not yet sufficiently advanced to permit definite statements to be made. The immediate need is for further research into the biology and host-parasite relationships of the worm in order that practical methods of control can be devised.

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U.S. Nematologists meet in Puerto Rico

The annual meeting of a U.S. technical committee, which is engaged in the study of plant parasitic nematodes and their control, was held at the Agricultural Experiment Station of the University of Puerto Rico at Rio Piedras, Puerto Rico early this year. Dr. L. F. Martorell and Dr. G. Steiner, a world authority on nematology, acted as hosts for the group, which conducted its activities under the direction of Dr. R. A. Chapman, Kentucky Agricultural Experiment Station Chairman, and Dr. Coyt Wilson, Alabama Polytechnic Institute Administrative Adviser. Representatives from 13 North American States and from Puerto Rico attended the meeting.

During their stay in Puerto Rico, Mr. R. G. Napier, General Manager of The Shell Company (Puerto Rico) Limited invited the visiting group and officials of the Puerto Rico Agricultural Experiment Stations to cocktails and a buffet supper at the Shell Club.

Left to right in this picture are Mr. Napier, Dr. Wilson, Dr. Martorell, Dr. Skinner and Dr. Chapman.

PART 2

Insecticide resistance in disease-carrying insects

by **J. R. Busvine,** Ph.D., D.Sc., *Reader in Entomology as Applied to Hygiene, London School of Hygiene and Tropical Medicine.*

This article has been adapted by the author from the second half of his paper, 'Insecticide-Resistant Strains of Insects of Public Health Importance', published in the Transactions of the Royal Society of Tropical Medicine and Hygiene, Vol. 51, No. 1, pp. 11-36, 1957. *An article adapted from the first half of this paper was published in the last issue of* Span *(April, 1958); in this the author considered important examples of disease-carrying insect species which have become resistant to insecticides.*

While it is difficult to assess some of the reports of insecticide resistance, it is clear that this trouble is impeding the control of more and more insects of public health importance. So far, no effective way has been found of regaining the activity of an insecticide to which resistance has developed. Indeed, it may well be said that the problems of resistance are growing faster than our capacity to deal with them. This was the opinion of the WHO Expert Committee on Insecticides, expressed at a meeting in July, 1956. It was agreed that the matter is serious and the committee recommended that the WHO should act as a co-ordinating body, to facilitate an international attack on the problem.

Already, a good deal of progress has been made. Standardized tests for resistance have been developed for human lice and for adult and larval mosquitoes. (The test method for adult mosquitoes is illustrated in the accompanying diagram). Test kits, assembled by the WHO, have been sent to field workers in many parts of the world. As a result, a considerable body of data is accumulating on natural and abnormal resistance levels.

Any attempts to answer practical questions about resistance immediately expose our fundamental ignorance. What we urgently need to know is whether resistance is liable to develop in every insect pest, towards any type of insecticide, if the latter is used extensively and for long enough. The happenings of recent years show that resistance has developed more rapidly and extensively in some situations than others; but we do not know how much this depends on the species concerned and how much on the insecticide and the way it is used.

Several years ago the author suggested that the chances of developing resistance quickly depended on three things:—

The frequency and importance of genes conferring resistance in the original population of insects;

The intensity of selection (i.e. the size of the population exposed to insecticide and the proportion killed); and

The number of generations per year.

These three factors require further examination.

Potentialities for developing resistance

Extremely little is known about the occurrence of genes for resistance in natural wild populations of pest insects. There are some reasons for expecting them to be very rare before they are concentrated by selective mortality due to wide use of insecticides. Therefore we have to base our speculations largely on information about existing resistant strains.

Some quite recent experiments with a dieldrin-resistant strain of *A. gambiae* seem to have given clear-cut results (DAVIDSON, 1956b)—perhaps because this resistance is of a simple, but highly developed kind. On the other hand, results of a dozen different investigations on DDT-resistance in the housefly and about the same number concerning induced resistance in

Drosophila melanogaster have produced a welter of confusion. Various authors have ascribed DDT-resistance in *Musca* to a single recessive gene, a single dominant gene, multiple genes, cytoplasmic inheritance and mixtures of several types (BUSVINE, 1957). This confusion appears to be due to two causes: first, there may be several factors concerned in resistance, which are inherited in different ways; secondly, the subject is more difficult to investigate than it appears and the techniques both of genetics and of measuring resistance have not been adequately refined.

It seems quite feasible that there may be two kinds of resistant genes: those giving generalised resistance and those conferring specific protection from a particular poison.

Generalised resistance has been called "vigour tolerance" by HOSKINS (1956). It may be due to various hereditable physiological characters (such as size, or resistance to starvation or desiccation) which would be expected to promote survival after treatment with any insecticide. Reduced permeability of the cuticle or increased lipoids in the body (WIESMANN, 1956) would raise resistance to a variety of hydrocarbon insecticides. On analogy with other variable biological characters, one might expect such attributes to be controlled by multiple genes and one would not expect the change to be very large.

It would seem very likely that resistance depending on genes of this type may develop in any species, if it is subjected to selective mortality pressure by any toxicant, for long enough on a sufficient scale. From the practical point of view, the importance of such low-level generalised resistance depends very much on the safety margin available with the particular control measure concerned. To give a concrete example: it unfortunately seems that the control of some mosquitoes by residual spray treatments has only a small margin of efficacy. It is true that some mosquitoes, like *A. darlingi* and *A. maculatus*, are very sensitive to DDT; but other forms, such as *C. fatigans*, have a naturally low susceptibility, so that a small additional increase will render them virtually immune.

Genes conferring highly specific resistance to a particular type of poison are likely to promote a biochemical defence mechanism. This could either mean a specific detoxifying enzyme or the introduction of a metabolic system unaffected by the poison. Examples of both are known. The DDT-dehydrochlorinase enzyme in resistant houseflies is one mechanism which protects them from this poison. The hydrogen cyanide resistant scale insects are believed to have developed a cyanide-insensitive respiratory system.

It seems that specific resistance mechanisms confer much higher resistance than vigour tolerance and, furthermore, they appear to be due, at least in some instances, to single genes. A characteristic of this type of resistant strain is that laboratory colonies of very high levels of immunity can be readily produced, presumably by selection of homozygous colonies. Whether these are liable to develop and remain stable in the field is another unanswered question.

The nature of a biochemical defence mechanism is obviously specifically connected with a particular type of insecticide. It would be of great interest to know how widely distributed among different insects are the potentialities for developing those mechanisms we have already encountered. As a first step, it would be helpful to know if the strains of various insects which already show resistance, depend on similar defence mechanisms.

Three general kinds of resistance have become prominent recently: to DDT and analogous compounds; to gamma BHC and compounds of the chlordane type; and to organophosphorus insecticides.

Types of DDT-resistance

Since resistance in the housefly has been far more extensively investigated than that of any other species, it would seem reasonable to use this as a basis for comparison. So far as one can judge, DDT-resistance in the housefly depends on more than one defence mechanism. Some excellent biochemical work has proved that a part of the resistance depends on an enzyme which converts DDT into the harmless compound DDE (2, 2-bis-(p-chlorophenyl)-1, 1-dichlorethylene), (STERNBERG *et al.*, 1950; see also review by METCALF, 1955). This enzyme seems to be present in all resistant strains and absent, or nearly so, in susceptible ones; it is probably an important factor in fly resistance. It may be, however, that this is not the only cause of resistance.

Measurements of relative resistance to a series of compounds analogous to DDT sometimes reveal different patterns (or resistance spectra) in various resistant strains of flies or other insects. This suggests that there may be more than one defence mechanism involved. Dehydrochlorination, for example, would not be expected to be an effective protection from substances like prolan (1, 1-bis-(p-chlorphenyl)-2-nitropropane) or dianisyl neopentane; yet some resistant strains are automatically resistant to these compounds. Protection other than by detoxication may derive from reduced penetration to the site of action or from absorption of poison in lipids.

Turning now to resistant strains of other insects, we find that a strain of body lice resistant to DDT was found to be also resistant to DANP (BUSVINE, 1953). Biochemical tests show that both resistant and normal

lice can degrade DDT, so that it is difficult to judge whether this is a cause of resistance or not. The DDT is changed to a water-soluble derivative, so that DDE is either not formed, or is changed to something else.

Some biochemical experiments with DDT-resistant *A. aegypti* from Trinidad have shown that larvae of this mosquito can change DDT to DDE, *in vivo* (BROWN, 1956). However, it has not been possible to extract the enzyme and perform the conversion *in vitro*, as it has with houseflies (STERNBERG *et al.*, 1954). Tests with analogues of DDT support the impression that the resistant *Aedes* depend on a dehydrochlorination mechanism.

Resistance to gamma BHC, chlordane, dieldrin, etc.

After the housefly had become resistant to DDT, other chlorinated insecticides were used; but it was soon found that when a new resistance developed, either to chlordane or to gamma BHC, the flies had automatically acquired resistance to several other insecticides (BUSVINE, 1951). This group resistance was eventually found to include the following: gamma BHC, chlordane, heptachlor, dieldrin, aldrin, endrin, isodrin and toxaphene. It would seem that a single mechanism is responsible (at least, partly) for resistance to the whole series, though it may be more efficient against some than others. Some workers found that resistance developed highest to the compound used for selection (DECKER and BRUCE, 1950); but my own research suggests that the order of resistance is basically independent of the chemical used for selection (BUSVINE, 1953). Resistance in four colonies of resistance flies from different countries was, in all cases, developed as follows: chlordane = dieldrin = aldrin > gamma BHC > endrin = isodrin.

Evidence of the same resistance to the same group of insecticides has been found in other insects as shown in table below.

In most of these cases, only approximate measurements of relative resistance were made; however, the results with *A. gambiae* are most interesting (DAVIDSON, 1956a). The levels of resistance are in the following order: chlordane > dieldrin = aldrin > endrin = isodrin > gamma BHC. The order is not greatly different from that shown by *Musca*, except that gamma BHC has fallen below isodrin and endrin. Another interesting fact is that a separate strain of *A. gambiae* from an adjacent area treated only with gamma BHC has given the same "resistance spectrum" as the one from the dieldrin-treated zone.

The conclusion seems to follow that resistance to the group of insecticides mentioned above depends on a similar mechanism in several different species. Very little can be said about the nature of this mechanism; biochemical studies of it have been so far limited to gamma BHC, owing to technical difficulties in estimating minute quantities of the other insecticides. Evidence from two sources is accumulating to show that the isomers of BHC are absorbed more slowly and metabolised more quickly by resistant houseflies than susceptible ones, though the difference is not so great as to explain the large divergence in susceptibility (BRADBURY and STANDEN, 1955, 1956a; OPPENOORTH, 1956). The resistant *Anopheles gambiae* from North Nigeria did not show any enhanced rate of degradation of BHC (BRADBURY and STANDEN, 1956b).

Resistance to organo-phosphorus insecticides

Comparatively little is known about resistance to organo-phosphorus insecticides, perhaps because they have been less extensively used, especially for insects of public health importance. Measurements of relative resistance have been made on several fly strains taken from areas in Denmark where organo-phosphorus treatments were beginning to fail (KEIDING, 1956). The results showed that the use of parathion induced resis-

Pest species	*Exposed to*	*Resistance developed to*
C. fatigans	gamma BHC	gamma BHC, dieldrin.
C. tarsalis	toxaphene, aldrin ..	toxaphene, aldrin, gamma BHC, heptachlor.
A. gambiae	dieldrin	dieldrin, aldrin, chlordane, gamma BHC, endrin, isodrin.
C. lectularius	gamma BHC	dieldrin, aldrin, chlordane, gamma BHC, endrin, isodrin.
B. germanica	chlordane	chlordane, dieldrin (gamma BHC).
Boophilus decoloratus ..	gamma BHC	gamma BHC, chlordane, dieldrin, toxaphene.

tance to diazinon and to "Bayer 21/199" (3-chloro-4-methyl-umbelliferone-0, 0-diethyl thiophosphate) as well as to parathion. Whichever of these three compounds was used in the field, the flies seemed to have built up higher resistance to "Bayer 21/199" than to the other pair, for which resistance increased only two or three times.

Intensity of selection and development of resistance

Generally speaking, a potential resistance will develop faster with more intense selection. The matter requires close examination; it involves both genetical and ecological considerations.

Genetical aspects. As has been pointed out by CROW (in press), it is to be expected that the greater the proportion killed in each generation, the more rapid the increase in resistance (excluding, of course, insecticidal effects giving 100 per cent. kill, which are exceptional in practice). While this seems to be generally true, the matter is somewhat complex and dependent on certain characteristics of the genetical mechanism involved. Thus, the resistance may be inherited through single or multiple genes. The former permits only two or three genotypic levels of susceptibility (homozygous susceptible, heterozygotes, which may be like one of the parents, and homozygous resistant); but, with multiple genes, many gradations of susceptibility are possible. If single gene inheritance is responsible, the speed of selection depends on whether the resistance factor is dominant or recessive, because this decides whether the heterozygous first offspring are easily killed or not. Again, resistance may be genetically linked with some deleterious character which will tend to delay selection by the insecticide and to reverse its action when the insecticidal pressure is removed. The rate at which this might happen depends largely on the degree to which this hypothetical adverse character is really harmful. The evidence available suggests that existing resistant strains are not linked with very harmful characters; in some cases they seem actually more viable than normal.

A number of genetical studies of resistance have been done. They are by no means easy to conduct, for certain technical reasons, and furthermore it is difficult to apply results obtained with small, inbred laboratory colonies to the vast natural populations in the field.

Ecological aspects. There are only the most rudimentary quantitative data about the intensity of selection by insecticides in the field. The degree of selective mortality imposed by an insecticide depends on the proportion of the natural populations coming into contact with it. In some cases the selective effect will be effectively countered by dilution, because the survivors inter-breed with individuals which have never been exposed to insecticide.

Some authorities have suggested that larvicidal treatments (e.g. against flies or mosquitoes) are more effective in promoting resistance than insecticide used against the adults. This would not be unexpected if the larvicide reached a higher proportion of the total population (as by aerial spraying) or if the toxic action lasted longer (as in poison mixed in manure); whereas action against the adult would be confined to random contacts of such adults as actually enter houses.

It may be noted that insecticides may selectively destroy strains characterised by different habits. Thus, where house-haunting and wild races of a mosquito co-exist, the former may be exterminated and the latter will survive. Perhaps this is what has happened in Sardinia, where long after the end of the island-wide DDT-spraying campaigns, the remaining *Anopheles labranchiae* seem to keep away from houses (AITKIN *et al.*, 1954). This is analogous to the mechanism by which behaviouristic resistance might be expected to arise; selection might favour a race with a changed reaction to insecticide, such as abnormally developed avoidance of DDT. However, it should be emphasised that there is very little evidence of this at present.

Number of generations per year

When resistant genes exist in a population, it seems reasonable to suppose that the speed of selection of a resistant strain will depend on the numbers of generations per year. Many of the species which have developed resistance have short life cycles; but some have not, as shown by the following rough estimates. ("Tropical" is taken as a mean temperature of 25° C.; "mild temperate" as six months at 18° C. and six months at 8° C.).

	Approx. generations per year	
	Tropical	*Mild temperate*
A. aegypti, *A. gambiae*, *A. sundaicus*, *A. stephensi*, etc. ..	30	—
M. domestica	25	7
P. humanus (on clothing) ..	16	16
C. lectularius	8	2
B. germanica (indoors) ..	2½	2

Since *Blattella* showed resistance no later than *A. aegypti*, it seems unlikely that reproduction rate is

of overwhelming importance. However, where a species has a very wide range of distribution, one might expect it to show resistance first in tropical zones. This seems to be true in regard to *C. lectularius*. *M. domestica*, however, developed resistance mainly in sub-tropical areas. It may be recalled, also, that the first instance of DDT-resistance was reported in Sweden.

Counter-measures against resistance

Three kinds of action to oppose resistance are possible: prevention; early detection; and cure.

Prevention of resistance. The fragmentary nature of our basic knowledge of resistance makes it difficult to recommend sound practical ways of preventing the development of resistance. Possibly the only sure way of preventing development of resistance is by avoiding the use of a particular insecticide. Thus, it might be feasible to stop using DDT powder for sanitary control of lice and fleas and to save this valuable weapon for a typhus or plague epidemic. Alternatively, since DDT has already been widely employed, a ban might be placed on some good alternative insecticide, such as gamma BHC, in order to keep this in reserve for an epidemic.

For some time, there have been suggestions that resistance could be prevented, or at least delayed, either by using mixtures of insecticides differing in mode of action or else by alternating from one to another. Unfortunately, there is little direct evidence on the matter, and theoretical speculations are based on untested assumptions. Nevertheless, since mixing or alternating insecticides are among the few readily practicable measures against resistance, we must consider the merits of each.

Alternation. The value of alternation of insecticides depends largely on the rate of decline in resistance after selection pressure is removed. Unfortunately, the long life of residual insecticides like DDT makes it impossible to stop their selective action sharply. Furthermore, as we have already noted, the harmful effects of resistant genes in the absence of insecticide seem to be slight. Therefore, recession is likely to be very slow indeed after the initial fall. Probably a period of the order of 10 years is required before reverting to the use of DDT for controlling houseflies. At the end of this time, the best that could be hoped would be a two-year effectiveness of DDT, comparable to its initial use in 1945.

Mixtures. The selective effect of a mixture of two insecticides depends very much on whether the susceptibility of the insects to the two compounds is positively correlated, negatively correlated or independent.

If susceptibility to the second insecticide is positively correlated with that to the first, the mixture will merely act as a higher concentration of the original compound, so that selection for resistance will be intensified. In the somewhat unlikely event of the actions of the two poisons being inversely correlated, the effect will be highly synergistic. Since the survivors from compound "A" will be the individuals most sensitive to "B", it should be easy to obtain complete kills of all individuals contacting the mixture. Unfortunately, no such combination of poisons has been discovered.

The most likely event is that resistance to B would be quite independent of A (since their modes of action are different). Crow (1952) believes that a mixture of poisons would be less satisfactory than alternation. His argument is as follows: If compounds A and B, at given rates, each cause 90 per cent. kill, they will together cause 99 per cent. mortality. Selection for resistance to either will be at the 90 per cent. level. Alternatively, one could use a higher rate of A or B alone to give 99 per cent. kill. Crow calculates that 10 years' selection at the 90 per cent. level will produce one-third more increase in resistance than five years at 99 per cent., followed by a change to another compound. His calculations assume multiple factors for resistance, and also that the resistance levels of progeny of survivors will have a normal distribution. Both these points seem dubious and it seems that calculations of this kind will be more fruitful when we have more data on which to base them.

One interesting suggestion, which seems to fall between mixture and alternation, is to apply one type of insecticide as a larvicide and use another against the adults.

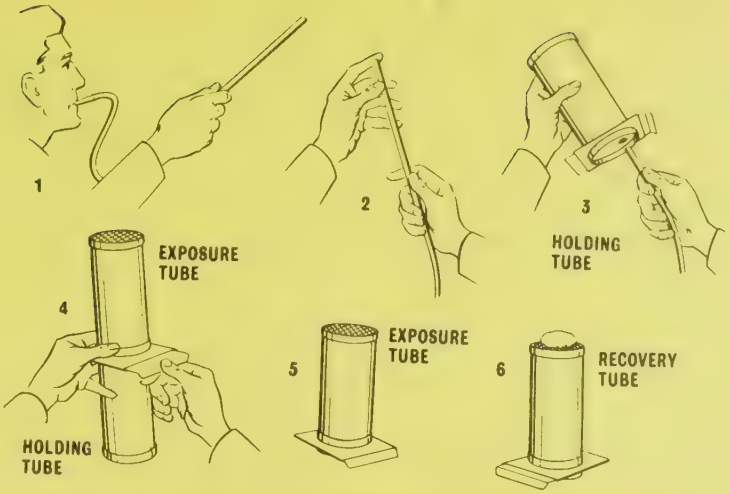
Early detection of resistance. Resistance is most likely to develop as a result of the widespread and systematic use of insecticide in organized control campaigns. In planning such schemes, therefore, adequate tests of susceptibility should be made before the start of operations and at intervals afterwards. Wherever possible, tests recommended by the World Health Organization should be used. In this way, reports of failure in the field can be speedily checked to determine whether they are due to a resistant strain or to some other cause.

Overcoming existing resistance. Where resistance is of a low-level 'vigour tolerance' type, it is possible that increased dosage or a more efficient method of application will solve the problem. However, this is unlikely to be of help in combatting high-level specific resistance.

If we had complete knowledge of the mode of action of insecticides and of the various defence mechanisms of resistant strains, we might be able to devise means of circumventing the protective system. Something like this was nearly achieved when so-called synergists were added to DDT to inhibit the detoxifying enzyme present in resistant houseflies. At first, this regained

THE METHOD OF DETECTING AND MEASURING RESISTANCE IN ADULT MOSQUITOES NOW ADVOCATED BY THE WORLD HEALTH ORGANIZATION

(1), (2), (3) Collection of mosquitoes in the pre-test holding tube. (4) The holding tube is connected to the exposure tube which has been lined with appropriate impregnated paper (supplied by WHO) a slide is removed, the mosquitoes blown down into the exposure tube and the slide replaced. (5) The holding tube is removed and the mosquitoes exposed for one hour. (6) Procedure (4) is reversed, so that the mosquitoes are returned to the holding tube (lined with clean paper), in which they are kept for 24 hours before mortality counts. (This method gives results directly comparable with the Busvine/Nash test, which has been widely used for the same purpose.)



much of the original power of DDT; but unfortunately, strains soon developed which were resistant to the DDT-synergist combination (probably because they depended on an alternative defence mechanism).

In general, our ignorance of the toxicology of insecticides is such that anti-resistance measures cannot be based on fundamental knowledge. In fact, the only course open at the moment is the obvious one of changing to a different type of insecticide. We cannot even forecast how long a new type of insecticide is likely to remain effective. The only evidence derives from the housefly, which developed a second type of resistance (to the chlordane-gamma BHC group) even more quickly than the original immunity to DDT. However, these data are too few to generalize.

The possibilities of changing to alternative insecticides are more limited than is generally imagined. The three types of resistance described in the previous section embrace nearly all the effective new synthetic insecticides, developed by intensive testing in many countries in the past 25 years. Perhaps, too, it is not mere chance that resistance is rare toward insecticides like pyrethrum which do not give the persistent residual action of the chlorinated hydrocarbon insecticides. Recent attempts to prolong the residual life of organophosphorus insecticides by adding chlorinated terphenyls (HORNSTEIN *et al.*, 1955) may render them more suitable for malaria control programmes. But, at the same time, this may increase their liability to develop resistance.

Instead of changing to another insecticide, another possibility is to change to other measures. Prior to the introduction of cheap and highly effective residual insecticides, many pests were controlled by altering the breeding site to render it unfavourable, or by introducing parasites and predators. While these measures should be borne in mind, most of them are no adequate substitute for the insecticides, because, either on account of expense or for other reasons, they cannot be used over very large areas. However, certain measures may be feasible if resistance develops in the later stages of a campaign. Thus, where the use of insecticides for several years has drastically reduced a disease such as malaria, it may be possible to eliminate the residue by distribution of drugs, though that might not have been a feasible measure originally.

Another method which might succeed after the insect population had been greatly reduced by insecticide consists of releasing males sterilized by radio activity, which in turn prevent the females with which they mate from breeding. This very interesting new method of pest control was successful in eradicating screw worms from the island of Curaçao (BUSHLAND *et al.*, 1955).

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Killing Broomrape in Tobacco

The parasitic weed, broomrape (*Orobanche ramosa*) causes serious damage to tobacco—and certain other crops—in various part of the world. In tobacco, the extent of the damage varies according to the age of the plant when it is attacked: young plants may be killed, while in older plants the leaves become so dry and straw-like as to be commercially worthless.

In Cuba, where *Orobanche* is a menace to tobacco growers, the weed begins to appear in the middle of December; it is abundant a month later, and dies out by the end of April. Its small seeds, similar to those of tobacco, may remain dormant in the soil for many years, only germinating when they are close to the roots of plants which *Orobanche* can parasitise.

Tobacco growers in Cuba try to avoid damage by broomrape by planting early and harvesting the crop before the middle of January. But sometimes early planting is not possible, and then broomrape may cause severe damage if it is not controlled.

Until recently, the only measures which could be taken to control *Orobanche* were cultural ones, but two or three years ago experiments at the Cuban Tobacco Experiment Station at San Juan Y Martinez showed that allyl alcohol, when sprayed in a concentration of 10 ccs. per gallon of water both on to the parasite and on to the soil around the tobacco, killed the parasite without damaging the tobacco. The allyl alcohol was applied in the form of Shell A-A Weed Seed Killer, one gallon of which is sufficient to treat approximately 18,000 infested tobacco plants.

The *Orobanche* treated with allyl alcohol began to turn blackish at the soil surface two or three days after treatment and then dried downwards from this point, the roots of the parasite becoming detached from the plant. The aerial part of the broomrape was less affected, though it did eventually die.

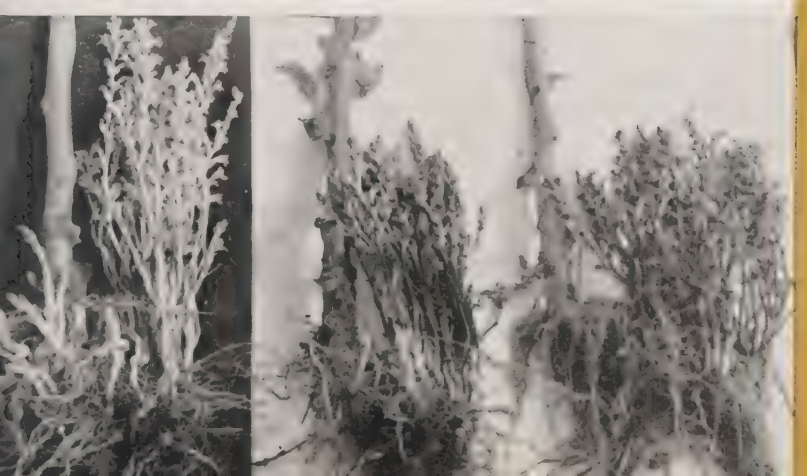
The quality of the leaves from tobacco plants treated with allyl alcohol was quite normal.

The accompanying photographs are of trials carried out by Cia. Petrolera Shell de Cuba S.A. In this work it was found to be essential to use a high volume nozzle; fan or low-volume nozzles did not give a sufficient coverage to obtain a rapid kill of the parasite. It was also found that to eliminate *Orobanche*, the tobacco needed to be treated as soon as the parasite was first noticed, and that treatment must be repeated once a year for as long as any broomrape continues to appear. In these trials, the action of the A-A Weed Seed Killer was accelerated where ten plants were treated immediately before or after watering.

Tobacco plants covered with cheese cloth to diminish light intensity and increase development, elasticity and fineness of the leaves (which are used principally for wrapping cigars). The leaf droop which is noticeable in this field is a symptom of broomrape infestation.

Tobacco plants infested by Orobanche; *these plants developed before becoming infested, the crop having been planted early so that it could be harvested before the appearance of the parasite.*

Shell A.A. Weed Seed Killer being diluted in preparation for spraying.



Tobacco plants before and after spraying with allyl alcohol solution. Left: *untreated.* Centre: *two days after treatment; note the darkened, rotting area of the dying broomrape.* Right: *three days after treatment; the rotting of the broomrape has spread but the host plant is not affected and the roots of the parasite can be easily separated.*

Britain's First National Silage Demonstration

SPONSORED BY SHELL

British farmers were recently given a unique opportunity to study the latest methods of making high quality silage and to examine the considerable range of machinery and equipment which is now available for the purpose.

The occasion was the United Kingdom's first national silage demonstration, a two-day event, attended by some 17,000 farmers, research and advisory workers, which was held in May on the Hampshire farm of Mr. Rex Paterson, a pioneer of silage making—he invented the buckrake—and one of its foremost exponents.

Sponsored by Shell Chemical Company Ltd., the demonstration was organised by a committee representing such interests as the Ministry of Agriculture, Fisheries and Food, the National Farmers' Union, and agricultural machinery and dairying research institutes, together with members from the sponsoring company.

Since the last war, silage has shown a remarkable increase in popularity as a feed for dairy stock in England and Wales, as the following production figures (provided by the Ministry of Agriculture) show:

	tons
1947	252,000
1952	1,591,000
1957	3,024,000

Stated at its simplest, the reason for this tremendous growth in silage production is that farmers have come to realise that well made silage can provide heavy crops of forage with relatively small loss of nutrients—in haymaking, on the other hand, nutrient loss is usually considerable—and that the cost per unit of Starch Equivalent in silage is generally about half that in root crops and less than that in hay.

As has been pointed out in a recent article by Professor S. J. Watson (Shell Chemical Company's *Land* 2), to avoid the disadvantages—'stemminess' and reduced nutritional value—inherent in grass cut at the early-flowering stage (when hay is usually cut), the crop must be cut at an earlier stage of growth, and since haymaking is then impossible some other conservation process must be used. While, Professor Watson states, artificial drying would technically be the best solution to this problem, it is not an economic proposition on the average farm, and silage making has shown itself to be the most suitable method under average conditions.

Silage, then, should be made at the leafy stage if it is to be used as part of the milk production ration. Such silage, Professor Watson continues, is really a watered concentrate and will replace the usual mixture of oilseed residues and cereals commonly used in dairy cake or meal. About 20 lb. of good leafy silage will replace the 4 lb. of the concentrate mixture normally fed for a gallon of milk.

Silage made at the early-flowering stage, however, while richer on a comparable dry matter basis than ordinary hay, is not rich enough by itself to take the place of a concentrate mixture; but 20 lb., if well made, should replace 2 lb. of concentrate and 4 lb. of good hay.

With the increase in the popularity of silage, much progress has been made in the development of machinery for its production, and many examples of the types of equipment now in use were to be seen at the demonstration. These comprised buckrakes, green crop loaders, pick-up balers, and a large number of different kinds of forage harvester. Examples of these machines at work are shown in the photographs on the following pages.

Self-feeding of silage to cattle, shown opposite, is an increasingly popular method of feeding this material. Its main advantage is a saving of time and labour otherwise required for carting the silage, and at the same time it eliminates handling—an unpopular task because of the weight and smell of silage. For self-feeding, a depth of about 6 ft. of settled silage is aimed at. The electric fence in front of the silage prevents waste and is set to control the amount fed daily. **(turn to page 18)**

Above: *Part of the general scene at Hatch Warren Farm, Basingstoke, Hampshire, while the U.K.'s first National Silage Demonstration was in progress there in May. The event was sponsored by Shell Chemical Company Limited.*

Left: *Self-feeding of silage* (*see note at foot of opposite page*).

Photo. Farmers Weekly

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SILAGE HARVESTING

The photographs on these two pages were taken at the British National Silage Demonstration in May (see p. 16)

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1 *A buckrake being used to fill a silage clamp with material which had been cut by a forage harvester and dumped near the clamp. The walls of the clamp are built of railway sleepers.*

2 *A Massey-Ferguson pick-up baler picking up cut material, baling it, and loading the bales into a trailer.*

3 *A green crop loader, the Wilder Steed, with self-emptying trailer from which the material picked up by the loader will be dropped direct on to the silage clamp. This machine is picking up grass cut by a mower.*

4 *The British Wilder Sila-Master forage harvester, a machine which is capable of cutting direct or picking up from the swath.*

5 *An American-designed forage harvester, the Lundell, in action. This flail type harvester, which is capable of cutting direct (as here) or of picking up a cut swath, is now being made in Britain as well as in the U.S.A.*

6 *This Australian forage harvester, the Grasslands, employs a flail cutter and, as can be seen, incorporates a built-in trailer, which is self-unloading.*

7 *The Danish Taarup flail cutting forage harvester; like other machines of its type, it cuts, lacerates and loads the crop in one operation.*

8 *The British Silorator forage harvester, this machine, which cuts direct with a rotary blade, has been developed from a stationary silage lacerating machine.*

9 *A German forage harvester, the Koela, picking up cut material from the swath.*

Four main types of machine are in use for harvesting silage: the buckrake, the pick-up baler, the green crop loader and the forage harvester. The first three are used to pick up green material that has been cut by a mower; forage harvesters cut and pick up. Examples of each are shown here, at work at the demonstration.

Points to be considered before choosing a machine or deciding on a system include the quantity of herbage to be handled; the labour required; the number of tractors and trailers required; and whether the machine chosen can be used for other purposes on the farm.

The buckrake is suitable when the hauling distance is short, and is probably the cheapest method of making silage under these conditions. Capital outlay is low.

The pick-up baler can be successfully used with a small team and is especially useful when very long hauls are involved. If the bales are properly stacked in the silo they can be easily removed when the silage is being fed, and baled silage provides a useful method of estimating the quantity fed. Among the disadvantages of this method are the difficulty of ensiling very lush herbage without treatment, and the possible high cost of producing the silage.

The green crop loader is essentially a machine for use where long hauls are involved. Care is needed in planning a system of using these machines to reduce labour wastage to a minimum.

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The forage harvester, while an expensive machine, and one which necessitates the use of special modified high sided trailers for carting the silage, has a direct beneficial action on the fermentation in the silage: the chopping or lacerating action of the machine facilitates the production of a well made silage. With chopped grass, too, consolidation is easier, and this helps to reduce waste in the silo.

These notes have been compiled from the booklet, *Grass Silage*, written by Dr. J. C. Murdoch, of the National Institute for Research in Dairying, for the benefit of those attending the demonstration.

International Co-operation in

by **V. E. Wilkins,** O.B.E., Ph.D., *Director-General of the European and Mediterranean Plant Protection Organisation*

Member States of the European and Mediterranean Plant Protection Organisation (EPPO) are shown in green.

Crop Protection

The European and Mediterranean Plant Protection Organisation, or EPPO, as it is commonly called, was built up on one pest alone, the Colorado beetle. It thus provides a good example of the wisdom of testing the possibilities of practical international co-operation by starting in a small way. If it is found that confidence can be developed between national official services in regard to an individual pest which is disturbing international trade, then that same trust can form the background for wider developments.

That is what happened in the case of EPPO. The few western governments represented on the International Colorado Beetle Committee, created in 1947 on the initiative of the United Kingdom, soon discovered that it was possible to establish definite and practical co-operation in controlling a pest which was not only doing damage to a crop of importance in all countries, but was interfering with international trade in agricultural products. Once that discovery was made, the demand for an extension of activities was natural, for there are other pests and diseases, besides the Colorado beetle, which interfere with trade, and can only be dealt with adequately by co-ordinated action between governments.

So three years later, in 1950, the International Colorado Beetle Committee, which had proved its effectiveness and recruited more member governments, transformed itself into the European Plant Protection Organisation, with responsibilities extending to other pests and diseases disturbing international trade. Although governmental, it was still an informal body. The following year, in April, 1951, the Organisation was placed on a formal basis by the signing in Paris, by representatives of fifteen governments, of what is known as the EPPO Convention. A little later the words "and Mediterranean" were added to the title. Subsequently, other governments joined the Organisation, which now has a membership of 23.

So much for the historical background. We now turn to some of the work which has and is being done, starting with the Colorado beetle campaign. When the International Committee took up its task the position in Europe bordered on the desperate. During the war, this pest (*Leptinotarsa decemlineata*) had spread through most of western Europe: Holland was invaded; Denmark was threatened; Great Britain and the Channel Islands were in jeopardy. Moreover, in most countries insecticides and spraying machinery were in short supply.

The Committee approached its problem from two directions. First, by vigorous propaganda, it endeavoured to make western governments and their farmers conscious of the fact that the beetle was a menace that threatened not only their crops but their export trade to beetle-free countries, and that it must be controlled for both these reasons. In this attempt the Committee succeeded. With few exceptions the beetle is now under control in all countries of western Europe. The propaganda included, among other things, the production of a colour film in four languages, which has been shown to numerous audiences throughout western Europe.

Control Campaigns

The second line of approach was the organisation of special co-ordinated control campaigns in certain areas which were felt to be especially dangerous as sources of beetle 'migration' from one country to another. Five such campaigns were initiated; in the Cotentin peninsula of France, regarded as the region from which swarming beetles could under favourable conditions reach the Channel Islands; in part of the Pas-de-Calais Department of northern France, which was felt to be a conceivable springboard from which the pest could reach south-east England; in the northern part of Schleswig-Holstein, from which beetles could spread to Denmark; in eastern Bavaria, threatening Austria and Czechoslovakia; and in north eastern Italy, threatening Austria and Yugoslavia.

Financial Organisation

The financial framework of the five campaigns was broadly similar. Where possible, the government which they were intended to benefit paid part or all of the extra cost involved. In certain cases the Committee provided financial assistance. In the French campaigns, help was also given by the French Ministry of Agriculture. In all cases the campaigns, having been run on an international basis for three or more years, have been taken over and continued by the governments concerned as an integral part of their normal plant protection programme. The role of EPPO is now simply to ensure that as far as practicable the special efforts are not allowed to slacken.

As for results, Britain, the Channel Islands and Denmark are still free of beetle, but the campaign in Italy has not prevented the pest from spreading into Yugoslavia, where it is now firmly established. On the other hand, Austria has acknowledged the value of the Italian effort in stopping or substantially reducing the invasion of Carinthia.

The position of Great Britain is of special interest, since as a substantial importer of fruit and vegetables she is always open to the danger of importing unwanted beetles as well. About 1947, when the committee started work, many beetle colonies were being discovered each year in potato fields in southern England. They had to be dealt with on a policy of extermination, which is costly; moreover, the British Treasury was paying large sums annually for the preventive spraying of potato crops over a large part of south-east England. During the last few years, there have been no beetle outbreaks among potatoes, and the preventive spraying has been abandoned. Legislative restrictions on imports have certainly been a factor contributing to this result, but the carrying out of active control measures in the exporting countries has played an equally important part. And now, the position on the continent has so improved that the British authorities have been able to relax substantially their import restrictions.

The Colorado beetle has been dealt with at some length partly because it provided the original reason for establishing EPPO, but mainly because, speaking broadly, the same kind of approach can be made to any other pest which can be spread in similar manner. Given goodwill and confidence among national plant protection authorities, one can substitute some other pest for the Colorado beetle and act accordingly.

Fall Webworm Control

For example, the fall webworm (*Hyphantria cunea*) appeared in central Europe, probably from the United States, for the first time about 1940. Ten years later two of the EPPO member governments, Austria and Yugoslavia, complained of severe infestation with this voracious moth, whose caterpillars defoliate large trees and have a very wide range of hosts. EPPO quickly secured substantial help from the French, Federal German, Italian and Swiss Governments in the form of machinery and insecticides, to enable the two invaded countries to wage war on the pest, and also made a financial grant. The total assistance, though appreciable, was only a fragment of the sums which the Austrian and Yugoslav governments made available for controlling *Hyphantria cunea*, but the psychological effect of this international action was considerable.

Moreover, as the pest was new to Europe, scientific investigation of its biology was needed. For help in this direction an appeal was made to the Food and Agriculture Organization of the United Nations, which provided financial assistance for research in both the infested countries, and, in the case of Yugoslavia, helped to equip a special biological control laboratory built by the Government. FAO then arranged for quantities of several types of parasites which prevent *Hyphantria cunea* from becoming a dangerous pest in North America, to be sent to the laboratory from the USA.

The present position is that, through the measures adopted, the pest is no longer regarded as of special importance in Austria, but in Yugoslavia infestation remains severe. In that country it has spread as far west as Zagreb, which is not far from the Italian frontier, beyond which lies the important Italian natural silk industry. The mulberry tree is particularly attractive to *Hyphantria cunea*, so again a situation calling for international action is arising. At a meeting recently convened by EPPO in Trieste, representatives of Yugoslavia, the Federal Republic of Germany, France and Italy agreed on a special control campaign in the Zagreb area, in the hope that this may stop, or at least delay, the western spread of the pest. The campaign will be costly to Yugoslavia, but appreciable contributions will be made by other interested governments.

Some pests and diseases do not lend themselves to this kind of international approach. Three of those to which EPPO has devoted considerable attention—potato root eelworm, San José scale and potato wart disease—are of this nature. In such cases the Organisation has convened international conferences or working parties of specialists to examine the importance of the pest or disease, and make recommendations for the most effective means of control and the regulatory measures necessary to prevent introduction or spread. The recommendations have been submitted to governments, and are to-day reflected in the plant protection legislation of many countries of Western Europe.

Phytosanitary regulations present, in fact, one of the most important problems to which the Organisation has addressed itself. As between the various countries there is unfortunately a lack of uniformity, the regulations are sometimes very complicated, and at times the restrictions may not be justified on technical grounds. An EPPO working party of recognised authorities in the field met on three occasions and will meet again during 1958. Two reports have already been published. The recommendations made concern a great number of the difficult problems met with in carrying out phytosanitary control of imports and exports of agricultural produce.

Substantial economic losses are suffered in most

European countries from infestation of produce in store. This subject comes within the scope of EPPO, and here again a working party of experts has been established to explore the field and make recommendations on how much losses can be avoided or reduced.

When the European Productivity Agency was established a few years ago, under the administrative responsibility of the European Organisation for Economic Co-operation, a project was approved for sending a United Kingdom specialist on pests of stored produce (one of the members of the EPPO working party) on a mission to North and South America and to many countries of Europe and North Africa, to investigate the methods for controlling infestation in stored foodstuffs and other products passing into international trade. His report* has recently been published by the OEEC, from whom it is available.

A good deal of attention is being paid to the plant protection problems of the Mediterranean area. The two pests which are economically the most serious are the olive fly and the Mediterranean fruit fly. The first of these pests is the concern of FAO. On the Mediterranean fruit fly, EPPO has convened two international conferences and their reports contain comprehensive information on the biology and incidence of the pest, on methods of control, and on recommended phytosanitary measures.

So far as diseases are concerned, the main danger to the important Mediterranean citrus fruit industry is the spread of viruses. An EPPO working party has discussed the two most serious virus diseases of citrus —tristeza and xyloporosis—and following its report a well-known virologist has recently been sent by the Organisation on a mission to various Mediterranean countries, to study the virus problems on the spot. His report will shortly be made available. A similar mission to co-ordinate measures of control of the Mediterranean fruit fly, will be sent by EPPO later this year to all countries in the Mediterranean basin who wish to take advantage of this service.

Among other activities of the European and Mediterranean Plant Protection Organisation is the maintenance of a reporting service, through which efforts are made to keep plant protection interests in Europe and other countries up-to-date in regard to developments of control measures and changes in phytosanitary regulations. Annual reports are issued on the incidence and control of the main pests and diseases hindering international trade with European countries. By these and other means the Organisation hopes to be able to render a service, not only to its member governments but to others, and the fact that last year the Soviet Union joined the Organisation, that Poland will probably join shortly, and that other eastern governments are now considering the matter, encourages the belief that the hope is not illusory.

**Control of Pests in Stored Agricultural Products.* OEEC., 2 Rue André Pascal, Paris 16, France. Price 11s. 6d. (or 700 Fr. fr. or $2.00)

Colorado beetles (Leptinotarsa decemlineata) *feeding on a potato plant. The European and Mediterranean Plant Protection Organisation was formed in 1950 out of the International Colorado Beetle Committee.*

British Developments in Aerial Spraying

by **W. R. Caseby,**
Shell Chemical Company Ltd.

It is well known that for many years aeroplanes have been used in the United States and in certain other countries for crop spraying and top dressing, but only recently has this new use for aircraft been developed by British operators.

In the period from 1948 to 1955 a certain amount of experimental crop spraying and fertiliser application was undertaken by aircraft operated by British companies. Tiger Moths and helicopters were used and the principal sphere of operations was the Sudan, where spraying was required to control cotton pests and locusts. Following this work, experience was gained in Great Britain, mostly in the eastern counties, with the same types of aircraft.

Owing to the comparatively small size of fields in this country, small aeroplanes are far more economical to operate under British farm conditions than larger machines. Trials with a Bristol Freighter equipped as a high capacity fertiliser spreader were abandoned in favour of the smaller machines, usually adaptations of early types. However, the need for suitable new aircraft was apparent and two companies with experience of light aircraft production have independently produced new designs within the last two or three years. Thus Auster Aircraft Ltd. have introduced the Agricola, which can carry up to 1,680 lb. of fertiliser, or 144 gal. of spray liquid. The Edgar Percival EP.9 can transport a similar amount of material.

Recently the Auster company have produced an intermediate sized aeroplane called the Workmaster, which is capable of carrying 100 gal. of spray fluid. The hundred-gallon tank on the Workmaster is placed alongside the pilot to reduce the likelihood of the tank crushing the pilot in a forced landing. The makers claim that the tank is so designed that the pilot's visibility is not impaired and that safety is enhanced by the fact that the spray load can be dumped in five seconds if a sudden emergency arises. This machine is being equipped with the Britten-Norman rotary atomiser spray gear, described below, and will be capable of spraying up to 100 acres per flight. All these machines have powerful engines, large flaps for slow, steep landing approaches and are capable of operating from short unprepared strips. Such aircraft have not yet operated very extensively in the United Kingdom, though the EP.9 was used for top dressing and spraying on a small scale in 1957.

Although British operators have mainly used aircraft such as Tiger Moth trainers and Auster touring machines for agricultural work, they have developed equipment for fitting to the aircraft and this is, of course, as important as the design of the aeroplane itself.

One of the earliest forms of spray attachment to an aeroplane consisted of a pipe passing along the span of the wings with nozzles spaced along its length. The

liquid to be sprayed was contained in a tank and fed under pressure to the spray pipe or bar. While simple and cheap, the spray bar nozzles gave poor atomisation of the spray liquid. When a small nozzle aperture was used to improve atomisation, frequent blockages occurred. In recent years, however, two British firms, Britten-Norman Ltd. and Micron Sprayers Ltd., have collaborated to evolve a device capable of more perfect atomisation. With modern agricultural chemicals it is not necessary to drench the crop being treated with large visible quantities of spray, and Britten-Norman decided that an applicator was required for aircraft which would efficiently disperse an effective quantity of chemical concentrate per acre without the necessity of carrying a large amount of carrier, such as spray oil or water.

The outcome of their research was the Micronair rotary atomiser, which, in the author's opinion, is a considerable improvement on the rotary brush atomisers used in the United States. The use of this equipment reduces substantially the amount of diluent carried as it is designed for the concentrated spraying of ground crops, and it effectively sprays at the rate of 1 gal. per acre. Thus a Tiger Moth aircraft with a tank capacity of 45 gal. will spray up to 11 acres when fitted with a conventional spray bar and nozzle equipment, but the same aeroplane can, it is claimed, treat 45 acres, with as good results, when equipped with Micronair rotary atomisers. Commercial work, both in the U.K. and elsewhere, has shown that results from low dosage rates are as good as those obtained with normal ground spray rig equipment. Pests have been killed where no more than 0.2 gal. per acre of insecticide solution has been used.

In order to appreciate this ultra low volume spray technique three points need to be considered: droplet size; number of droplets; and strength of chemical. The volume of a droplet varies as the cube of its diameter. For example, the drop from a tap may measure about 5,000 microns in diameter. If this large drop were to be atomised into droplets of a uniform size of 500 microns, 1,000 droplets would result. At a uniform droplet size of 50 microns, one million droplets are produced. If, to be effective, a treatment requires a cover density of 500 droplets per square inch, the volume of liquid in the tap drop sprayed in droplets of 500 microns size would cover 2 sq. in. If the same amount of liquid is sprayed in droplets of 50 microns at the same cover density of 500 per sq. in., 2,000 sq. in., or one thousand times the area, can be treated. As the droplet size is reduced and the area covered increased, it is necessary to increase the insecticide concentration proportionately so that the correct dosage rate is applied.

It can therefore be seen that the question of droplet size is extremely important. The following table shows the effect of atomisation on coverage:—

Number of droplets per unit area for an application of 1 gal. per acre.

Diameter (in. microns)	*Volume (cu. microns)*	*Number per sq. mm.*	*Number per sq. in.*
10	525	1,780	1,148,100
20	4,200	222	143,190
50	65,520	14.30	9,224
100	525,000	1.78	1,164
200	4,200,000	0.22	142
300	14,175,000	0.066	43
500	.....	0.014	9

These facts show that any substantial departure from the droplet size selected as ideal can seriously affect the efficiency of the application. If a spraying system is used which does not give reasonably precise control of droplet size it is necessary to increase very substantially the application rate to obtain effective cover. This can be wasteful in chemical and effort.

Choice of Droplet Size

The chief factors affecting choice of droplet size are the type of chemical being used, the nature of the carrier liquid, prevailing conditions, and the crop to be sprayed. The use of small droplets ensures minimum run-off of the chemical, and makes possible a dense cover without risk of leaf scorch from phytotoxic materials. Furthermore, where a small dosage rate is possible, oil may be used as the carrier instead of water; the advantages of this include easier handling, reduction in losses by evaporation and improved fixing of the chemical on the crop. On the other hand, large droplets have the advantage that there is less likelihood of drift.

As a rule it is desirable to spray oil-based chemicals in fine droplets (under 80 microns) and water-carried chemicals in larger droplets (up to 150 microns).

The principle of all rotary atomisers is that liquid fed on to a rotating disc will be thrown off the periphery in droplets of uniform size, provided that the liquid has attained the full circumferential speed of the disc. The droplet size is controlled by the speed of rotation of the disc and its diameter. Practical application of the

The Auster Agricola agricultural aircraft. It is capable of carrying 1,680 lb. of fertiliser or 144 gal. of spray liquid.

spinning disc in agriculture is severely limited by the low rate of feed possible before slip takes place and rotary atomisation breaks down.

Multiple spinning discs and brushes have been tried, but, because of slip, commercial application with this equipment is not practicable at the rate of feed possible before rotary atomisation breaks down. The surface of the rotating cage of the Micronair atomiser maintains rotary atomisation up to a feed of several gallons per minute. Atomising capacity is a direct function of the surface area of the cylinder—a typical example being 4 in. in diameter and 14 in. long. The atomisers are driven by windmills and the blades are adjustable to give the desired r.p.m., and thus droplet size. The atomiser speed is normally between 10,000 and 15,000 r.p.m.

On a light aircraft, only two Micronair atomisers need be fitted. These are placed at the wing tips so that the spray is introduced into the wing tip vortices. This results in a wide double swathe. With a Tiger Moth operating in still air the overall width of the swathes is equal to about six wing spans, or sixty yards.

It is sometimes desirable to introduce a mist of atomised chemical into an air space, the object being to fill the maximum air space with a spray of lethal droplets. Uniform droplet size is important to ensure the largest possible number of droplets being obtained from the available spray liquid, and again the use of wing tip atomisers considerably increases the volume of air space which may be treated on each spraying pass.

Fertiliser Application

The development of equipment to spread fertilisers from aircraft in solid form has not progressed as rapidly as have spray applicators. It has been usual to fit a large hopper into the front cockpit of a Tiger Moth aeroplane or into a rear cabin of an aircraft such as the Auster Aiglet. A shutter in the bottom of the hopper allows the load to fall out into the slipstream. The principal difficulty with this method is that an uneven spread of fertiliser results. Furthermore, with most existing types of light aircraft not more than 4-5 cwt. of fertiliser can be carried. This is not a very economic load, and operators have often found themselves forced to avoid solid application and concentrate on liquid treatments.

The latest aircraft designed for agricultural work have improved types of hopper. The Auster Aiglet, for example, has a hopper gate for hydraulically controlled discharge (the capacity of the hopper is $\frac{3}{4}$ ton). The Edgar Percival Aircraft Company have likewise developed a hopper discharge outlet on their EP.9 aeroplane. Britten-Norman Limited have developed a specialised fertiliser distributor for installation in agricultural aircraft, and they state that this hopper can result in an even swathe width of 23 yd. when flying at 30 ft.

A new fixed-wing British machine which has become popular: Edgar Percival Aircraft Ltd's. E.P.9, shown potato spraying.

One important factor to be considered when dealing with solid fertilisers is the physical texture of the chemical itself—i.e., whether it is a dust, a powder or is granulated. A powder is difficult to discharge as it tends to block the orifice and does not flow evenly, and it is therefore necessary to agitate the chemical at the mouth of the shutter. A granulated substance, however, flows more smoothly through the gate, and has less tendency to cause a blockage; Nitra-Shell, for example, has proved completely satisfactory for aerial use, because of its even granulation. Urea is also available in granulated form, and during 1958 trials are being carried out to compare urea with Nitra-Shell when applied from the air to wheat and grassland.

The application of certain trace elements (boron, copper, manganese and zinc), nitrogen and phosphorus has been carried out on a limited commercial scale in England and Scotland, but more experimental and commercial work will be necessary before information is available to show whether or not it is an economic and effective proposition.

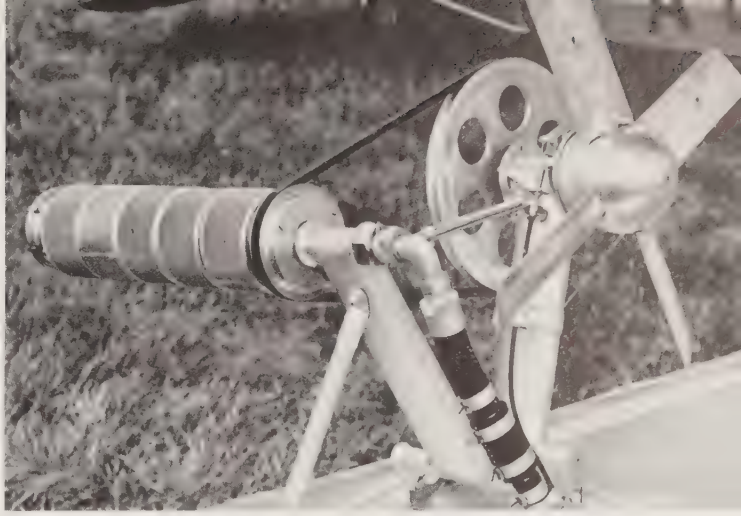
Other Aerial Treatments

The crop which has probably received, in the U.K., the greatest attention by aerial contractors is potatoes, because when controlling blight it is important to avoid unduly damaging the crop, and the driving of ground machines through a standing potato crop can result in a reduction in yield of up to ½ ton per acre.

A copper-in-oil concentrate has been evolved which is suitable for aerial application by low volume spray equipment of the rotary atomiser type. It is not suitable, however, for use through typical spray gear nozzles. Each gallon of this product contains 5 lb. copper, and the rate of application is usually 1 lb. copper per acre. Suitable carrier oils can be used to give a total volume of 1.2 gal. per acre of oil and copper concentrate.

Comparative trials with Micronair rotary atomiser equipment, using the copper oil concentrate, and conventional boom rigs spraying mercurised copper oxychloride wettable powder in water, showed that the copper in oil mixture at 1.2 gal. per acre gave as effective a cover as was obtained with 3½ lb. mercurised copper oxychloride with 3-4 gal. water per acre. The degree of fungus control was the same in each case. This is an important point when considering the economic payload of the aeroplane and the acreage it can spray in one day. Each tank load of 45 gal. of chemical can treat approximately 37 acres, whereas when the aqueous copper oxychloride mixture is used only 15 acres can be covered with one tank load.

The treatment of sugar beet and peas with insecticides has shown great promise, especially where an insect attack has developed in a crop which is so advanced in growth that to drive a tractor through it would cause severe damage. Aerial spraying for the control of mealy aphis of brassicas has also been carried out.



A Micronair rotary atomiser fitted to the wing tip of a Tiger Moth aircraft. This picture shows clearly the fan-driven rotating cylinder (10,000-15,000 r.p.m.) [*Photo: By courtesy of* The Aeroplane

The new Auster Workmaster, equipped with Micronair rotary atomisers, which can be seen on the wing tips.

During 1957, aerial spraying trials were carried out in Britain on apple and cherry orchards, and also in a mature walnut tree plantation. The application of insecticides and fungicides to orchard trees from the air will supplement the work of ground blast sprayers travelling along beneath the trees, and should prove especially useful in orchards where the trees are encroaching on one another, and also where the trees are of considerable height.

The spraying of herbicides was practised a few years ago on large open areas of cereals and grassland, but has been discontinued because of the risk of spray drift damage.

Looking ahead, much development work has still to be done before the agricultural aerial contractor finds an established place in British farming, and experimental applications are now being carried out to compare degree of coverage and control obtained by aerial application and by ground treatment.

PHOSDRIN

A new insecticide

by **A. G. Richardson,** *The Shell Petroleum Company Ltd.*

Government authorities in many countries are becoming increasingly concerned with the possible danger to the consumer from crops containing toxic insecticide residues, and have therefore introduced regulations stipulating the minimum period which must be allowed to elapse between the application of a particular insecticide and the harvesting of the crop. Generally speaking these intervals may be anything from three months to two weeks, depending on the toxicity and persistence of the chemical.

This article describes Phosdrin, a new organo-phosphorus insecticide developed by Shell which, from its properties and mode of action, meets all the main requirements for close-to-harvest applications.*

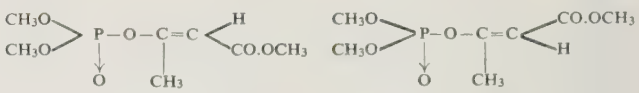
**Phosdrin is a Registered Trade Mark*

Insect invasion of crops which are about to be harvested is by no means an uncommon occurrence and losses from such circumstances can be considerable. Vegetables tend to suffer these predations more frequently than other produce if only because they come to maturity throughout the entire growing season. In many cases the method of dealing with such attacks presents a formidable problem to the grower since the standard insecticides available to him may either leave unacceptable toxic residues on the crop or, if non-toxic, may be insufficiently effective controlling agents.

A new systemic insecticide, Phosdrin, now provides the means to overcome this problem. Phosdrin is fast acting, is highly toxic to a wide range of insects, but despite having the high mammalian toxicity associated with most organo-phosphates, is sufficiently short-lived that crops are, in most cases, safe for consumption one to two days after application. In addition, it has the advantage of a rapid and efficient systemic action.

Understandably, since the use of Phosdrin on a commercial scale has, so far, been confined to the USA, authorities in other countries are not necessarily in agreement as to what constitutes the minimum safe interval between its last application and harvest. In the USA, with two years' commercial experience, this interval is one to four days depending on the crop, whilst in the United Kingdom, Holland and France, where Phosdrin is being sold this year for the first time, this minimum interval has been fixed at three, four and seven days respectively.

Chemically, Phosdrin is a mixture of the cis and trans isomers of 2-carbomethoxy-l-methylvinyl dimethyl phosphate, the configurations of which are as below:—



cis *trans*

Biologically, one of these isomers, arbitrarily designated *alpha*, is some 10-100 times more active than the second, or *beta*, isomer and Phosdrin insecticide, by definition, contains at least 60 per cent. of the more active isomer.

At normal temperatures Phosdrin is a liquid which is completely miscible with water as well as with ketones and aromatic hydrocarbons. Its property of water solubility allows for its application in aqueous solution, but since it is subject to hydrolysis it is not possible to store the material after dilution with water. The commercial product is therefore sold either as 100 per cent. material, or in dilution as an emulsifiable concentrate with an aromatic hydrocarbon as solvent. For an insecticide, the vapour pressure of this compound is moderately high (0.0029 mm Hg at 21°C) and hence, in addition to acting systemically and by direct contact, it has appreciable fumigant action. This property also aids in the rapid dissipation of residues from leaf surfaces.

With regard to its systemic action, penetration of Phosdrin through the roots and foliage of plants, followed by upward and lateral translocation, takes place very rapidly, but thereafter enzymatic breakdown of the material commences with the result that, after 24 hours, residues from normal applications are less

than 1 p.p.m. By means of radio-active labelled material, CASIDA (1) has shown that in young plants the *alpha* isomer has an average half-life of 0.86 day and the *beta* isomer of 2.0 days. The exact compositions of the resulting breakdown products are not known with certainty but the important factor has been established that these are relatively non-toxic. Soil applications of Phosdrin, although effective, are not generally practised since higher dosage rates must be used and the subsequent action is slower than with applications to the aerial parts of plants.

The high biological activity of this insecticide and its range of usefulness are illustrated by the data in Table I, in which its activity against six typical test insects is compared, under laboratory conditions, with parathion and malathion.

As an aphicide, Phosdrin in most cases achieves virtually 100 per cent. kill at dosages as low as 70 gm. per hectare. The following table (Table II), summarising work by STERN and REYNOLDS (2), illustrates this activity in relation to the spotted lucerne aphid (*Pterocallidium sp.*) in California.

A similar degree of activity has been shown for *Aphis fabae*, *Myzus persicae*, *Brevicoryne brassicae* and *Nasonovia ribis-nigri*, the lettuce aphid. Undoubtedly, its potency and speed of action against aphids is due, in some measure, to its systemic action and to its volatility. In addition to aphids, Phosdrin has been shown by field trials to have the same high toxicity to other sucking and rasping insects such as thrips, mealybugs and spider mites. Against the latter it also operates as an ovicide. (*Continued on next page.*)

TABLE I. INSECT TOXICITY OF PHOSDRIN INSECTICIDE

Toxicity Index (*a*) (*Standard=100*)	DIELDRIN		PARATHION		
Compound	*Housefly* (b) Musca domestica	*Large Milkweed Bug* (c) Oncopeltus fasciatus	*Southern Armyworm* (d) Prodenia eridania	*Mexican Bean Beetle Larvae* (d) Epilachna varivestis	*Pea Aphid* (b) Macro-siphum pisi	*Two-Spotted Spider Mite* (b) Tetranychus telarius
Phosdrin	120	69	130	120	110	360
Parathion	130	21	150	100	100	100
Malathion	5	17	54	15	35	32

(a) Toxicity Index = $\frac{\text{LD 50 of standard} \times 100}{\text{LD 50 of sample}}$ (b) By direct spray. (c) Deposits on filter paper. (d) Deposits on bean plant.

TABLE II. EFFECT OF PHOSDRIN ON SPOTTED LUCERNE APHIDS

V. M. Stern and H. P. Reynolds, Hinkley, California

	Amount per hectare		*Days after treatment*			
			24 hours		*48 hours*	
Material	*Litres*	*Grams a.m.*	*Number Apterous Aphids per 100 stems*	*Per cent. Reduction from Untreated Plots*	*Number Apterous Aphids per 100 stems*	*Per cent. Reduction from Untreated Plots*
Phosdrin	100	90	112	99.4	26	99.9
	100	50	368	98.8	166	99.5
Parathion	90	160	7,195	76.8	4,957	85.5
Trithion	140	260	5,041	83.7	2,948	91.4
Untreated	—	—	30,890	—	34,095	—

Against the larvae of certain important lepidopterous pests Phosdrin has shown a degree of activity unusual for a phosphorus insecticide. The following unpublished data (Table III) of R. K. CHAPMAN illustrates the activity of Phosdrin against DDT-resistant cabbage caterpillars and cabbage loopers.

TABLE III

CONTROL OF *PIERIS RAPÆ* AND *TRICHOPLUSIA NI* (CABBAGE LOOPER) ON CABBAGES 5 DAYS AFTER APPLICATION KENOSHA, WISCONSIN, 1954

R. K. Chapman, University of Wisconsin

Insecticide	*Kilos a.m. per hectare*	Pieris rapae		Trichoplusia ni	
		Per cent. Control		*Per cent. Control*	
		Foliage	Soil	Foliage	Soil
Phosdrin ..	0.5	98	60	100	90
Demeton ..	1	98	19	68	47
Malathion..	1	70	—	42	—
Parathion ..	0.25	79	—	16	—
Average No. insects per 24 heads in check ..	—	47	—	19	—

Kills in the region of 100 per cent. have also been achieved in trials against *Plutella maculipennis* and several species of Tortricidae at a dosage of 280 gm. per hectare; this is generally twice the dosage normally used for sucking insects. Other important groups of biting insects, notably sawflies, weevils and chrysomelid beetles, exhibit a degree of susceptibility similar to that of the larvae already mentioned.

TABLE IV

TOXICITY OF PHOSDRIN TO MAMMALS

	Acute Oral Toxicity LD_{50} mg/kg.		*Cholinesterase inhibition Human Red Blood Cell*
	Rats (male)	*Mice (male)*	*ID_{50}*
Technical Phosdrin	5.0	7.1	2.3×10^{-6} molar
Alpha isomer ..	2.9	4.1	1.5×10^{-6} molar
Beta isomer ..	46	59	1.9×10^{-5} molar
Percutaneous, in propylene glycol, LD_{50} for rabbits .. .. (KODANA *et al.* [3])			33.8 mg/kg.

The high mammalian toxicity of this compound has already been referred to. Table IV contains some basic data on this aspect in relation to laboratory animals.

Chronic feeding tests on rats have established that there is no accumulation of sublethal dosages and recovery after feeding such dosages is rapid. Naturally, because of its oral and dermal toxicity, full precaution must be taken when handling and using Phosdrin to avoid inhalation or skin contact.

So far in this paper, Phosdrin has been considered principally for close-to-harvest applications. However, its short residual life invokes the question—to what extent does its lack of persistence restrict its usefulness for conventional applications? The answer to this is very much dependent on the habits of the pest concerned, the time of year and the prevailing weather. Where regrowth of a population is due more to the influx of migrants than to high reproductive rate of survivors, the short life of this compound is a disadvantage. Under the reverse conditions, however, i.e. where high reproductive potential is a more potent factor in build up than migration, then the excellent initial kill may result in a control lasting as long or longer than that achieved with a more persistent but less active material.

Indeed it is fast becoming realised that, despite short persistence, a wide spectrum of control and a high insecticidal activity confers on Phosdrin a range of applications far outstretching the limited use on food crops close to harvest originally envisaged. Thus, in addition to the now established uses on vegetable and fruit crops, Phosdrin has a potential application for the control of a range of sucking and chewing insects and mites on forage crops, tobacco, cotton and ornamentals. At present, trials on these extended uses of Phosdrin are being undertaken throughout the world. Phosdrin, in fact, is showing itself to be a potent systemic phosphate insecticide with the particular advantage that harmful residues dissipate within a short time of spraying.

This article has been adapted from the paper "Phosdrin —A new insecticide for vegetables", presented by the author at the 15th International Horticultural Congress, Nice, April, 1958.

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BOOKS

A New Approach to Malaria Study

The Epidemiology and Control of Malaria. GEORGE MACDONALD, C.M.G., M.D., F.R.C.P., *Director of the Ross Institute of Tropical Hygiene, and Professor of Tropical Hygiene, University of London.* Oxford University Press, London. 30s.

In some two hundred pages of closely reasoned discussion and explanatory matter, Professor Macdonald has presented the new approach to the study of malaria and its control that his recent mathematical discussions of various of its aspects foretold. His aim is to show how biological and circumstantial data on the epidemiology and control of malaria may be related by mathematical techniques, and thus integrated into one coherent whole.

The first four chapters, occupying nearly a quarter of the book, explain the many factors concerned in malaria epidemiology—the mechanics of transmission, reproduction of infection in man, sporozoite rates, parasite rates, acquired immunity and its effect, susceptibility of mosquitoes to infection, longevity of vector mosquitoes, and so on. The inter-actions and the mathematical treatment of such factors are explained.

The author classifies epidemics as long term (extending over centuries), periodic (occurring every few years), periodic seasonal (occurring annually), and irregular (such as those in Brazil and Upper Egypt after the introduction of *A. gambiae*). Epidemics are common only in areas of 'malaria instability,' where the vectors are usually partly or highly zoophilic and relatively short-lived, climatic conditions are not always suitable for mosquito production and the completion of the extrinsic cycle, and where people have acquired little or no immunity.

The studies involved in a malaria survey are dealt with in some detail. The values of the precipitin test, sporozoite and oocyst rates, experimental huts for insecticide assessments, and tests for the measurement of mosquito susceptibilities to DDT and dieldrin, are described and stressed. All essential factors in the survey are given mathematical expression, a line of approach which is given prominence.

In a chapter on insecticides, the properties of DDT, BHC and dieldrin are compared: dieldrin, the author states, is now the most widely used insecticide in residual spraying for malaria control. Diazinon and malathion are mentioned as of probable value against resistant mosquitoes; and pyrethrins and synergists in space sprays are briefly dealt with. Formulations of these compounds are described and their uses are indicated.

Professor Macdonald emphasises the desirability of ordering only those insecticides which conform to the specifications of the World Health Organization, and of having large quantities checked by a competent chemist. Techniques for the assessment of surface deposits after spraying are described. The author points out that world-wide use of these compounds indicates that hazards are negligible if spilling and splashing and leaky equipment are avoided, and if operators wash thoroughly and frequently. He recommends the use of visors for all operators, and of well ventilated protective clothing in addition for those handling dieldrin.

The organisation required for adult or larval control is described, and Professor Macdonald rightly places emphasis upon the importance of well-drilled men in the spray gangs. He discusses the difference between malaria eradication and mosquito vector eradication: the former, consisting of a reduction of vectors accompanied by treatment of all infected people, appears to hold out most promise of quick results.

Drugs are considered in connection with prophylaxis and mass treatment. The uses and effects of chloroquine, amodiaquine, proquanil, and pyrimethamine are set out and a plea is made for more trials in the use of some of these in pilot malaria eradication experiments, and in preventing relapses or the importation of *P. vivax*.

On mosquito susceptibility and resistance, Professor Macdonald outlines some of the work done in his laboratory which led to the discovery that resistance of *A. gambiae* to dieldrin, and of *A. sundaicus* to DDT, was due to the presence of a gene. The author states that the gene can be detected by 'discriminating' doses of insecticide. These are employed as an extension to the susceptibility tests recommended by the WHO for use before and during insecticidal operations against mosquitoes. The author emphasises that since development of resistance by selection cannot be avoided if the gene is present, the choice of insecticide in any control project should be restricted to one or more of the same group; but he stresses that fear of resistance should not be allowed to hinder operations—whether imagicidal, larvicidal or both.

In an appendix, the author presents a full mathematical treatment of the dozen or so interacting factors of which the malaria problem is composed. A second appendix

deals with techniques employed in surveys and control operations.

References and literature for wider reading are given at the end of each chapter, and there is an adequate index.

Professor Macdonald has brought to the study of the greatest public health problem of the tropics and subtropics a precision of thought and expression which must have a profound influence on future studies of malaria. Whether or not its mathematical treatment proves attractive, the book will certainly be of great value to all scientists, public health officers, health inspectors, field officers, and administrators interested in the problem.—C. B. Symes.

Soil Science for the Layman

The World of the Soil. Sir E. John Russell. New Naturalist Series, Collins, London. 25s.

The declared aim of the New Naturalist Series is to interest the general reader in the wild life of Britain by recapturing the inquiring spirit of the old naturalists. The soil forms an essential basis for much of this wild life as it is the natural medium for the growth of most green plants which in their turn provide the first links in the food chains of all animals. Hence it is not surprising to find a volume in this series devoted to soils.

In this book the author sets out to give the educated layman a broad outline of our present state of knowledge of the complex world of the soil. As is fitting in a volume in this series, emphasis is placed on the biology of the soil and on its utilization by man. There can be few people more highly qualified than Sir John to write such a book, for his long life has been devoted to the study of the soil and the complex problem of its use by man for the growing of his crops. His work started as chemist at Wye College, where he collaborated with Sir Daniel Hall to produce their classic survey, *The Agriculture and Soils of Kent, Surrey and Sussex*, and then continued at Rothamsted Experimental Station, where he succeeded Sir Daniel as Director in 1912. He remained there for over 30 years, in the course of which the Station developed under his guidance as the centre for soil research in the Commonwealth.

Sir John Russell's book, *Soil Conditions and Plant Growth*, has been for very many years—the first edition appeared in 1912—the standard work on its subject throughout the world, and there can be few students of agricultural science in the last two or three decades who have not been grateful at some time or other for his lucid exposition of this difficult field. Now, in his retirement, Sir John has written a book for the naturalist and farmer which cannot fail to fascinate and entertain the reader, whilst the student will find it a helpful introduction to the subject. *The World of the Soil* is clearly written and is free from all unnecessary scientific jargon.

The book begins with a short account of the origin of soils from the underlying rocks and of the complex nature of the mineral skeleton of the soil as revealed by X-ray photography. This is followed by a chapter on the origin of humus from the decomposition of plant and animal remains and the influence of this organic matter on soil properties. The next section provides a concise account of the various factors such as aeration, water conditions, temperature and soil reaction which govern the living conditions in the soil for plant roots and the various soil inhabitants.

These three introductory chapters prepare the way for a fascinating account of the diverse organisms which live within the complex framework of the soil. Not only are they of interest in themselves but their activities markedly effect the soil and its fertility. It is this veritable world of organisms, largely hidden from ordinary eyes, that the author had in mind in the title of this book, and these two chapters, the one concerned with soil micro-organisms—' the invisibles,' as Sir John calls them—and the other concerned with the larger animals such as earthworms and nematodes, constitute well over a third of the book, and provide what is probably the best introduction to soil biology available to the English reader.

The author now gives an account of man's scientific control of the soil as a medium for crop growth. The development of our knowledge of plant nutrition and fertilisers is described, and there are shorter discussions of the problems of soil structure, maintenance, liming and the control of soil water by irrigation and drainage.

There follows an account of the nature and utilisation of the different kinds of soils in the British landscape—sands, loams, clays, chalk soils, peats and high-lying soils are the types recognized. This discussion of soil types is restricted to a textural and geological basis and the reader is not introduced to modern concepts of soil morphology, genesis and classification. From the point of view of the naturalist and ecologist this is a disappointing chapter, for field studies in soils are of great interest and value to them. There is little in this chapter to stimulate the reader to go and look for himself at the great variety of soils to be seen in the forest, heath, pasture or arable field. Such study of soils out of doors does not require complicated apparatus, and it seems a pity that this aspect of soil studies has been neglected in this book.

Sir John Russell concludes his book with two brief chapters on soil survey and analysis and on the producti-

vity of British soils. There is a classified bibliography and the book is illustrated with some 45 photographs, including two colour plates, and 11 diagrams.

This book can be thoroughly recommended to the reader who is anxious to learn of the scientific principles underlying soil management. The technical agriculturalist should find it very useful as a means of revising his knowledge of soils, whilst the agricultural student could not hope to find a more readable or lucid introduction to applied soil science.—G. P. ASKEW.

Soil: The 1957 Yearbook of Agriculture. Edited by A. STEFFERUD. The United States Department of Agriculture. Washington, D.C. $2.25.

The USDA 1957 Yearbook of Agriculture, *Soil*, is concerned principally with soil management, but it contains sufficient background information on soil science and classification, together with a glossary of terms used by pedologists, to enable the subject to be understood by the non-scientific reader.

The scope of the book may be judged from the main headings of the table of contents. Thus the first section, ' Principles,' consists of nine articles on the elements of soil science. A section entitled 'Fertility' deals with plant nutrients, and soil organic matter, living organisms and toxic elements. 'Practices' is a section containing twelve papers on subjects ranging from the determination of nutrient needs to the application and economics of fertilisers. 'Soil Care' is the title of a section concerned mainly with cultivation and control of erosion and of soil pests and diseases.

Other sections are entitled 'Moisture,' 'Systems,' 'Regions' and 'Special Uses.' 'Systems' deals with cropping and farming systems, and with soil classification and surveys and the use of soil maps. Under the heading ' Regions' is a series of articles dealing with soil management problems in different parts of the USA, and the final section,' Special Uses,' deals with soil management techniques for different individual crops and conditions.

Advances in Pest Control Research, Volume I. Edited by R. L. METCALF, *Citrus Experiment Station, University of California, U.S.A.* Interscience Publishers Ltd., New York and London. $11 or 88s.

This book is the first in a series which, the publishers state, will bring together the most recent advances in all aspects of the applied science of pest control. It contains 14 separate papers (two of them by British, the remainder by US authors) on a wide range of pest control subjects, the contents being as follows:—

Control of health hazards associated with the use of pesticides, by J. M. Barnes, Toxicology Research Unit, Medical Research Laboratories, Carshalton, England. The chemistry and mode of action of herbicides, by A. S. Crafts, University of California. Uses of radio-isotopes in pesticide research, by Paul A. Dahm, Iowa State College. The chemistry and action of organic phosphorus insecticides, by T. R. Fukuto, University of California. Mechanisms of fungitoxicity, by James G. Horsfall, Connecticut Agricultural Experiment Station. Recent advances in control of soil fungi, by J. B. Kendrick, Jr. and G. A. Zentmyer, University of California. Repellents for biting arthropods, by G. F. Shambaugh, R. F. Brown, and J. J. Pratt, Jr., Entomology Section, Army Quartermaster Research and Engineering Center, Massachusetts. The status of systemic insecticides in pest control practices, by W. E. Ripper, Fisons Pest Control Ltd., Bourn, Cambridge, England. Chemical analysis of pesticide residues, by Milton S. Schechter and Irwin Hornstein, USDA Agricultural Research Service, Beltsville. Bioassay of pesticide residues, by Yun-Pei Sun, Shell Development Company, Denver.

The Publishers state that the second volume of *Advances in Pest Control Research* is due to be published in September, 1958.

The comparision of High-and Low-Volume Spraying Techniques on Fruit and Ground Crops. Monograph No. 2, Society of Chemical Industry, London. 18s.

The 11 papers read at a spraying symposium organised by the Pesticides Group of the Society of Chemical Industry in December, 1956, together with the discussions, have now been published by the Society as a monograph which can be bought by non-members.

The subjects covered are: concentrate spraying—fungicidal aspects; orchard trials with undiluted lime-sulphur; spraying on potatoes and in pine plantations; the development of low-volume spraying methods with special reference to fruit; commercial value of various low-volume techniques used in fruit tree spraying; large-scale application of low-volume sprays.

Levels and distribution of deposits; spray techniques for fruit; droplet formation and assessment; the development of air-assisted fruit-spraying machinery; and the application of low-volume spraying in East Africa.

Beneficial Insects. B. D. MORETON. Bulletin No. 20, Ministry of Agriculture, Fisheries & Food, H.M. Stationery Office, London. 5s. 6d.

This bulletin, which was first published in 1922 and of which the last edition appeared in 1939, has been entirely re-written by the present author who, by writing in a simple language, has managed to give a fascinating account of a difficult subject.

The booklet is of interest to growers and scientists alike. Growers will add greatly to their biological knowledge and will get a glimpse of the intricacies of the insect world as far as it affects agricultural crops, while scientists may find a review of Britain's common pests and predators most useful.

Additional chapters on biological control of insect pests and the effect of chemicals on beneficial insects enhance the value of the booklet. It is a useful work in which the author should be congratulated.—A. M. H. SANGER.

Reducing the Cost of Blister Blight Control

by **B. N. Webster,** *Servicio Shell para el Agricultor, Venezuela.*
Formerly pathologist, Tea Research Institute of Ceylon.

Ever since it was first discovered that a 50 per cent. copper fungicide afforded adequate control of the blister blight disease of tea when applied at 6 oz. per acre after each plucking round, considerable effort has been directed towards reducing the cost of protection. Three ways presented themselves:—

1. Reducing the labour costs of the operation by improving the output per man.

2. Reducing the cost of the fungicide by either cutting down the total amount of copper or using a cheaper filler.

3. Reducing the amount of 'standard' applied per acre.

The first could be achieved either by the use of mechanised equipment or by improvements to existing machinery. Both were attempted; but to date the use of mechanised equipment has not achieved a great deal of success as motorised mistblowers and power dusters of sufficiently robust construction to stand up to the handling they would receive are almost invariably too heavy to be carried by one man over most tea estates. Two-man machines have been tried but were beaten by the terrain and the difficult nature of tea itself.

Much more success has been achieved by the introduction of double nozzles enabling two or even four rows of tea to be sprayed simultaneously, and by the introduction of pressure regulators to the standard pneumatic knapsacks in general use. Since 1951 the average output of work per man in spray protection has almost been doubled and output of three acres per man is now capable of achievement. On all but the most steep land, the average labourer can move fast enough to make the use of double nozzles worthwhile and their general use is strongly advocated.

The recent introduction of an improved method of assessment of blister blight control has assisted the Tea Research Institute in their investigation of price reduction by means of reducing fungicide costs. It has permitted the evaluation of much more accurate results than was previously possible when an arbitrary visual scale of assessment was used. During the last two years experiments with a reduced percentage of copper fungi-

cides and with reduced quantities of standard 50 per cent. copper fungicides have yielded some interesting and also unexpected results.

Firstly, it has been shown conclusively that in all but the very worst weather conditions 3 oz. per acre of a standard 50 per cent. copper fungicide will afford adequate protection of tea in plucking. This fact has been utilised by a few planters who regularly reduce the amount of fungicide applied as soon as weather conditions show some improvement. Secondly, a fungicide containing as little as 12 per cent. copper could afford satisfactory protection when applied at 6 oz. per acre, although not affording protection equal to that of 50 per cent. copper fungicide at either 6 oz. or 3 oz. per acre.

The implications of the above will be readily apparent. No longer will it be necessary to worry about exceeding the so-called 'permitted limit' of copper content in the made tea and no longer will it be necessary to wonder whether Ramaswamy Kangany is keeping his spraying rounds quite so close behind Ponnasamy Kanakapulle's plucking rounds as before. Considerable anxiety has been felt in the past on this subject of copper tolerances and it is therefore gratifying to record that in the USA the upper limit of copper content in foodstuffs has now been removed. There is every possibility that the Western European Union to which the UK belongs will follow suit.

Despite this there are still very good practical reasons why the planter should not be misled by specious arguments to the effect that he can now spray his tea two days before plucking. Who wants to? The object of copper spraying is to protect the leaf that is to remain on the bush, not that which will be plucked in two days' time. Analyses of teas plucked at varying times after spraying show that a considerable proportion of the copper applied shortly before plucking is removed (otherwise why bother about residues at all?) at plucking time, and the leaf that is left on the bush is left unprotected by the filtering out effect of the flush that is taken. Therefore, no departure of more than a day or two at the most should be entertained from the basic principle of applying protection as soon after plucking as is possible.

Despite these findings it is still impossible to give specific advice as to when a reduction in the application rate of copper fungicides is possible. In all trials to date the only time when 3 oz. of 50 per cent. copper fungicide has failed to give as good protection as 6 oz. of the same fungicide is during the worst six weeks of either monsoon. It is still up to the individual to decide for himself when a reduction is feasible. Some degree of guidance may be afforded by the amount of sun. There is a distinct correlation between hours of sunshine and blister blight incidence, and as soon as two to three sunny days per week are experienced, it should be possible to reduce copper applications.

The position may therefore be summarised as follows: equipment should be reliable pressure retaining knapsack sprayers with central charge pump, either manual or power, and should preferably be fitted with pressure regulating valves and double nozzle lances. Sprayers should be kept clean and well serviced. Spraying gangs should not be larger than eight to one charge pump unless power charging units are employed. The fungicide should be mixed on an acreage basis and not on a fixed concentration basis. It is always worthwhile to carry out a 'dummy run' over different types of ground to check the output of the gang.

Condensed from Shell Chemical and Agricultural News, *3rd Quarter, 1957, published by the Shell Company of Ceylon, Ltd.*

New Technique in Locust Control

Ultra-low-volume application of persistent insecticides has gained official recognition as a practical locust control technique with the publication by the Anti-Locust Research Centre, London, of a booklet describing the method.

Entitled *An Exhaust-Nozzle Sprayer for Ultra-Low-Volume Application of Persistent Insecticide in Locust Control*, the report, by H. J. Sayer and R. C. Rainey, of Desert Locust Survey, describes a simple spraying machine (designed by Mr. Sayer) which is operated by the exhaust gases of a Land Rover and which is used to produce a fine spray of persistent stomach insecticide. The insecticide is sprayed on to vegetation on which hopper nymphs will subsequently feed.

Dieldrin, formulated as a 20 per cent. solution in an oil fraction, is the insecticide which is recommended for use with the Sayer's exhaust sprayer.

The promising results which were obtained in the trials reported in this bulletin have since been confirmed in operational campaigns in Libya, Ethiopia and East Africa, and further trials have been carried out in Iraq and Iran.

Following the recommendations of the FAO Technical Advisory Committee on Desert Locust Control, which met in Rome in June, 1958, this technique will now be given extended trials throughout the desert locust region.

Mediterranean Fruit-Fly Eradicated in Florida

The recent initial appearance of Mediterranean fruit fly (*Ceratitis capitata*) in Florida, USA, was uncovered in April, 1956, when a resident of Miami contacted the county agricultural agent's office for information about larvae found in a grapefruit from a 'dooryard' planting.

The first invasion of the Mediterranean fruit fly was discovered in Florida in April, 1929, and eradication ended with the lifting of all quarantine regulations eighteen months later. The 1929 invasion was found near Orlando, in the heavily planted citrus area, and spread to 20 counties.

The 1956 infestation broke out in Miami, a large residential resort area, and spread to 28 counties. Whereas eradication efforts in the first fight were concentrated on a rural division of the state, with its heavy agricultural holdings, the second campaign hit hardest at urban areas and unlimited 'dooryard' plantings of a great variety of host plants. The 1956-57 campaign was officially closed in December, 1957. Both state and federal agencies consider the 'Medfly' completely eradicated since no trace of this insect has been found since mid-September last, and that find was only one of four reported since June, 1957.

The control programme in 1929-30 was based on a veritable 'scorched earth' policy in which host plants and produce were destroyed in eliminating possible breeding spots for the 'Medfly.' A field force of more than 6,000 men was needed to carry on this programme, gathering host fruits and vegetables, uprooting many host plantings and spraying host trees with baited lead arsenate containing molasses and sugar.

In contrast with the earlier campaign, fewer than 800 employees were needed in the 1956 programme. The use of insecticides, fumigants, and quarantines ultimately allowed the movement of practically all Florida's produce to markets throughout the world.

Ground and air applications were made of dieldrin as a soil treatment for killing Mediterranean fruit fly larvae entering the ground and killing the adult fly emerging from the pupal stage. The recommended treatment was 50 lb. per acre of 10 per cent. granular dieldrin, 30-40 mesh.

Aerial spraying of a mixture of 2 lb. 25 per cent. wettable malathion, 1 lb. of approved protein hydrolysate as bait, and enough water to make one gallon of liquid was used as adult fly control. This was applied at the rate of one gallon per acre.

Fumigation of harvested vegetables and fruits was accomplished by the use of ethylene dibromide and methyl bromide. The latter was used for most host vegetables at the rate of 2 lb. per 1,000 cu. ft. for a period of $3\frac{1}{2}$ hours. In fumigating citrus, eight ounces of ethylene dibromide per 1,000 cubic feet for a period of two hours proved sufficient, while mangoes required 10 ounces of the same chemical for the same space and duration.

To help prevent the spread of *C. capitata*, roadblocks were used in both campaigns to limit the movement of infested plants and produce. Many tons of host fruits and vegetables, which were not fumigated, were uncovered in checking more than four million motor vehicles in the 1956 campaign.

At the start of the 1956 campaign, a few thousand glass traps were used but failed to do the job properly. The problem was quickly solved by much cheaper and more efficient plastic models. There was a great variance in the number of traps used during the two campaigns: over 12,000 in the 1929-30 campaign, against 50,000 employed now. Trapping, which played and continues to play such an important part in eradication, will be continued as a regular part of the State Plant Board's inspection programme.

While no accurate record is available of the acreage sprayed in the first programme, aircraft have covered some 800,000 acres, one or more times, in the second campaign. The aggregate total covered has reached over six-and-a-half million acres.

State and federal appropriations for the first campaign totalled roughly $7 million while the second programme was financed by an appropriation of $10 million.

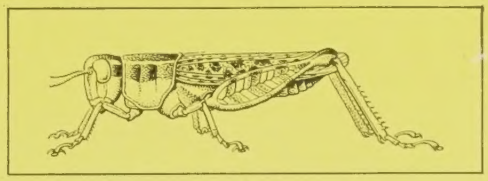
Fire Ant Control

Another pest which is currently the subject of a widespread control campaign in the USA is the fire ant, *Solenopsis* spp. During the past eighteen months or so this pest has infested some 20 million acres in 10 southeastern states.

Principally a pest of grassland, the fire ant is a menace in three ways: the mounds built by ant colonies may damage farm machinery; crop plants are often destroyed by the ant; and it stings humans and livestock, sometimes causing unpleasant infections.

Control is chiefly by ground or aerial applications of dieldrin or heptachlor, 10 per cent. granules being used at a dosage rate of 20 lb. per acre.

Island in a living tide



Here, when the earth was young, lay an inland sea whose western shore was the swelling foothills of the Andes. To-day, where vast herds of cattle graze and the hot, dust-soft wind whispers endlessly in the ears of the grass, a world of water once moved—and smoothed the earth to an unimaginable flatness. Stoneless, soft, immensely fertile, the Argentine *pampa* stretches sea-flat to the horizon. A sea without water, yet which knows a dangerous and deadly tide.

For the advance of the pampa grasshoppers is tide-like in its relentlessness. *Tucura*, the *criollos* call them, 'locust-like' in their seething numbers and clustering rapacity. Nothing green or growing is immune to their feeding. Only the leaves of the lonely, indestructible Ombú tree, generally spurned by all insects, sometimes survive. When the fierce tide has passed, the Ombú, traditional refuge of the pampas, is often alone and forlorn in a waste of destruction.

To-day however, on the *estancias* of San Luis, La Pampa, Buenos Aires and Córdoba, the precious grazing lands and forage crops of alfalfa are at last being protected—by dieldrin, developed by Shell. Of all the insecticides tried, none has proved more effective or more persistent. Applied from the air as a spray (150 gms. of dieldrin to 6 litres of diesel or gas oil per hectare—or 50 gms. to 2 litres, using the strip method) dieldrin not only controls *tucura*, but controls it *for at least 25 days after application.*

When it is borne in mind that infestation can spread over 10 million hectares annually, involving losses—in reduced meat production, devastation of pastures and diminished yields of alfalfa seed—approaching 60 million U.S. dollars, the value of dieldrin to the *estancieros* is clear. Whereas the Ombú is an island in the living tide of *tucura*, dieldrin is the wall which halts its flow.

dieldrin

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